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FINAL REPORT

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STUDIES ON BROILER CHICKEN TRANSPORTATION IN SASKATCHEWAN

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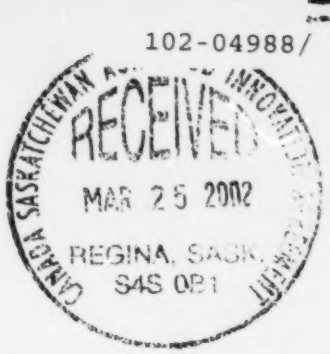

FINAL REPORT

March 19, 2002

PROJECT: SDAF#19990256-24BX
STUDIES ON BROILER CHICKEN TRANSPORTATION IN SASKATCHEWAN

H.L. Classen[1], T. Knezacek[1], G.P. Audren[1], S. Stephens[2] T. Crowe[3], E.M. Barber[3,4], A. A. Olkowski[1], M.A. Mitchell[5] and P.J. Kettlewell[6]

[1]Department of Animal and Poultry Science
University of Saskatchewan
Saskatoon, SK S7N 5A8

[2]Department of Veterinary Pathology
University of Saskatchewan
Saskatoon, SK S7N 5B4

[3]Department of Agricultural and Bioresource Engineering
University of Saskatchewan
Saskatoon, SK S7N 5A9

[4]Dean of Agriculture
University of Saskatchewan
Saskatoon, SK S7N 5A8

[5]Roslin Insitute
Roslin, Midlothian EH25 9PS, Scotland

[6]Silsoe Research Institute
Wrest Park, Silsoe, Bedfordshire MK45 4HS, UK

ABSTRACT/SUMMARY

Pre-slaughter management of broiler chickens under Western Canadian climatic conditions was studied, with emphasis on the transportation of broilers from farm to slaughtering plant. Data collection included evaluation of the barn environment and bird condition prior to loading, temperature and relative humidity on the trailer during transport, death during the trip, and bird condition upon arrival at the slaughtering plant. A total of 31 trips were monitored over an ambient temperature range of –27.2 to 21.9°C. Data from winter trips demonstrated that passive ventilation on tarped transport trailers produced a heterogeneous distribution of temperate and humidity conditions that was less than optimum for some locations. Crate temperatures near the floor and the back of the trailer were cold while core locations (front and centre) were warm. As ambient temperatures rose, environmental conditions improved with temperatures above -6°C providing an acceptable trailer environment. Trips completed when temperatures were less than –16°C had higher death loss (0.27%), but levels for all trips were low (0.11%). A higher death loss from farm to shackling (0.27%) demonstrated that lairage is an important aspect of pre-slaughter management. Recommendations were made regarding transportation of broilers and it was concluded that more research is required to improve ventilation of trailers during cold weather trips.

EXECUTIVE SUMMARY

Research was undertaken to study pre-slaughter management of broiler chickens under Western Canadian climatic conditions, with specific emphasis on the transportation of broilers from farm to slaughtering plant. Data collection included an evaluation of the barn environment and bird condition prior to loading, temperature and relative humidity conditions on the transport vehicle during transport, death during the trip, and bird condition upon arrival at the slaughtering plant. A total of 31 trips were monitored with four used to help define the principal research strategy and the remaining 27 to characterize vehicle environmental conditions over a wide range of ambient temperature.

The four preliminary trips completed in winter demonstrated that passive ventilation on tightly tarped transport trailers, while allowing birds in the core of the trailer to maintain body temperature, produced a heterogeneous distribution of temperate and humidity conditions that were less than optimum. The results demonstrated the potential for cold stress near air entry points and heat stress in poorly ventilated areas. Because the data loggers were not placed near the extreme outside of the trailer, it is probable that birds were exposed to colder temperatures than outlined above. Therefore, it was deemed essential to acquire a more complete picture of the temperature variability in subsequent research.

In the principle study, the primary focus was to comprehensively investigate horizontal and vertical temperature and humidity gradients on the trailer through continuous monitoring with data loggers. Barn environment and bird condition were assessed on the farm prior to

loading. Data loggers were placed in modules during loading and then the transport vehicle was followed to Wynyard where the trailer unit was driven into the live receiving area. Modules were immediately removed from the trailer and each crate was inspected. Bird condition was assessed and dead birds (DOA - dead on arrival) were removed and identified for necropsy. After processing, the plant reports were obtained for additional information, including the number of birds that died during the lairage period.

Journey length in the principle study varied from 140 to 240 minutes. The range of ambient temperatures was –27.2°C to 21.9°C. For all trips below the ambient temperature of 7.2°C, the tarps on the transport vehicle were lowered and secured on both sides and a variable number of roof vents was opened. At or above 7.2°C, one or both tarps were raised to provide increased ventilation, all roof vents were open, and front and rear vents were occasionally open at higher temperatures.

Ambient temperature affected the mean crate temperatures on the transport vehicle. The linear relationship between ambient temperature and mean temperature of the crates was stronger when the tarps were raised in comparison to when they were lowered. This is a reflection of the variable vent configuration and the impact of imperfect sealing of the tarps at the lower temperatures, in contrast to the more uniform and unrestrictive ventilation configurations at higher temperatures.

Some general temperature trends were obvious for most trips. Within a row of crates, the middle crate was warmer than those from the driver and passenger sides of the trailer. Under cold conditions, temperatures at the floor of the trailer for all stack locations were low. Similarly, temperatures were low at the back of the trailer (roof, centre, floor). The tarps used for the sides of the trailers are difficult to seal in these areas and as a consequence cold air infiltrates the load. The highest temperatures were found in the middle and upper front sections of the trailer. This appears to be due to the distance from areas of air infiltration and the natural forward movement of air on the load.

The open roof vent area affected temperature lift when the tarps were down. As open vent area increased from 0.18 m^2 to 2.0 m^2, there was a strong negative relationship between vent area and temperature lift (crate temperature minus ambient temperature); but once the vent area exceeded 2.0 m^2, the degree of temperature lift remained constant. This information indicates that air exchange can be controlled somewhat by the area of vent opening, particularly when adjustments are made to the front roof vents.

The degree of temperature lift was affected by tarp configuration for trips with an ambient temperature above 6°C. Temperature lifts of 3.3, 5.7 and 9.6°C were recorded when both tarps were raised, one tarp was raised and both tarps were lowered, respectively. With tarps raised, closed or open front and rear vent configuration had little effect on the mean crate temperature and mean temperature lift values.

Apparent Equivalent Temperature (AET) was used as an integrated index that combined dry-bulb temperature and relative humidity to give an indication of the effective bird temperature. This index revealed that cold ambient temperatures resulted in potentially dangerous conditions as a result of both cold and warm on-board temperatures in combination with high relative humidity. Observations of wet birds, particularly in the middle of the modules and core of the trailer, suggests that the moisture produced from bird respiration, and the low ventilation rate are the primary factors responsible for the high humidity conditions in the core of the trailer. At intermediate temperatures, the majority of conditions on the trailer are satisfactory. This was also true for warmer conditions although the possibility of high temperature/relative humidity conditions needs to be monitored particularly when the vehicle is stationary.

The level of death loss during 26 monitored trips was very low with a mean of 0.11% and a range of 0.05 to 0.52%. These values, associated with bird death occurring during the transportation period only, are lower than the Canadian average for 2000 (0.40%) and the average value found in a study from the UK (0.22%). However, the DOA data from this research did not include death losses occurring during the holding period prior to processing. Dead birds were categorized according to the major factors judged to be associated with death. These were transportation itself (34%), catching trauma (29.2%), farm-related death (31.9%), death as a result of our data collection (3.2) and other reasons not readily associated (1.4%). It must be emphasized that transportation may have contributed to death occurring in all categories but that other factors made the birds susceptible to dying. Ambient temperature affected the incidence of birds dying during transport with the incidence of DOA broilers being higher when the ambient temperature was < -16°C. Variability even within this temperature grouping suggested that factors such as farm management and specific management of the trailer units can affect this characteristic and that cold temperatures do not automatically translate to elevated death loss. Examination of incidence of dead on shackling on the monitored trips demonstrated that bird lairage plays an important role in pre-slaughter bird death (mean = 0.27%).

Overall, the barns visited in this study were well managed and contained birds in good condition. This may have played a role in the low levels of death loss observed.

Conclusions

Winter transportation of broilers in Saskatchewan presents a considerable challenge in terms of protecting birds from the cold and yet providing adequate trailer ventilation. Although roof vents can be used to control air exchange to some degree, passive air flow of this type is variable because of the influence of vent location, truck speed, prevailing winds, bird stocking density, etc. Similarly, air does not enter the trailer in a planned fashion since there are no planned inlets. Air enters primarily at the edges of the tarps (rear, bottom and front) as they are difficult to seal, through unintentional openings (poorly sealed front vents) or through roof vents. Ventilation efficacy is further reduced by modules containing broilers that block air flow and thereby influence the degree of ventilation that occurs in various sections of the trailer. The above factors result in

heterogeneous temperature distribution from very cold near air inlets to quite warm in poorly ventilated areas.

Recommendations to the processing industry for improving conditions in passively ventilated broiler transport vehicles are included in the report. Although we believe these recommendations will have beneficial effects, they will not eliminate all problems associated with cold weather transportation. Further engineering research is required to provide a superior transportation system for broiler chickens. This research is currently underway and is funded by a NSERC/AAFC grant. High temperature transportation provides acceptable on-board thermal conditions, provided that the vehicle remains in motion.

The transport vehicle is central to pre-slaughter broiler management and animal welfare, but farm management that produces healthy, dry birds will minimize the negative effect of stress during this period of time. Similarly the length of lairage and the quality of the lairage environment affect animal welfare and economic loss prior to slaughter.

TECHNICAL REPORT:

1. Introduction

Transportation of animals to slaughter is an essential component of an intensive and geographically dispersed industry where large numbers of birds must be transported from diverse locations to a central slaughter facility. Moving these birds in a wide range of environments poses a challenge from both economical and animal welfare standpoints. In transit, birds are exposed to a variety of potential stressors including temperature, moisture, acceleration, vibration, motion, impacts, fasting, withdrawal of water, social disruption and noise. As a result, live haul and associated problems are major determinants of the efficiency of broiler production by affecting factors such as death on arrival (DOA), trim at slaughtering and meat quality. The research described in this report will allow the Poultry Industry to understand biological changes affecting birds during transportation, and to make proper modifications to reduce financial losses and improve the welfare of birds between farms and the processing plant.

2. Objectives

The general objective of this research was to reduce economic losses and improve animal welfare during the transportation of broiler chickens. More specific objectives were:

- To identify and quantify the major components of transport environments and pre-slaughter management that constitute the major risks to the welfare of broiler chickens and affect the economics of broiler production under Saskatchewan conditions.
- To compare the pre-slaughter management and transportation conditions of broiler chickens in Saskatchewan.
- To make recommendations to the broiler industry which are designed to optimize the conditions for transportation.
- To develop training material for those involved in pre-slaughter management and transportation of broiler chickens.

3. Materials and Methods

Transportation vehicles

The transportation system employed in Saskatchewan utilizes Anglia Autoflow modules (Wortham Ling, Diss, Norfolk, England IP22 1SR) that are loaded by forklift onto a trailer unit (Figure 1). The modules span the width of the trailer and contain 12 or 15 crates, each holding 20 to 26 birds. The trailer, module and crate dimensions are given in Table 1.

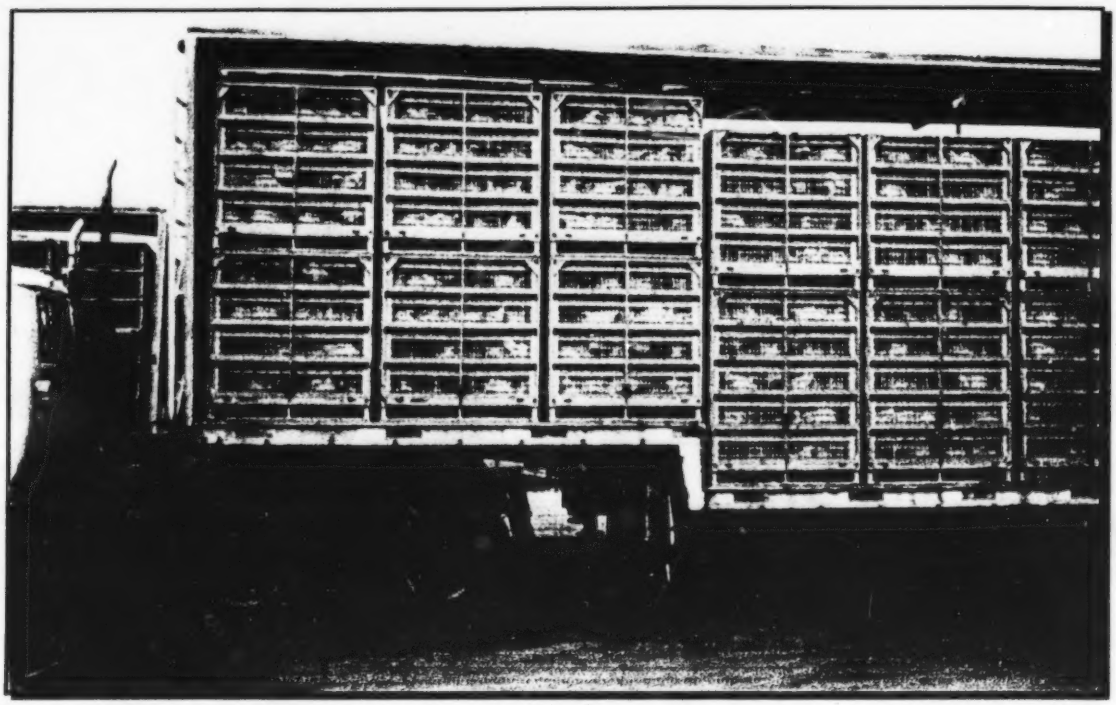

Figure 1. Typical trailer used for transporting broilers in Saskatchewan. Anglia Autoflow modules are loaded onto the trailer unit with a forklift and held in place with locating pyramids on the floor of the trailer.

TABLE 1. Dimensions of the broiler transportation trailer, modules and crates

Component	Section	Length (m)	Width (m)	Height (m)
Trailer	Anterior step in frame	3.74	2.50	2.80
	Posterior step in frame	12.27	2.50	3.10
Module	12 crates	2.44	1.17	1.15
	15 crates	2.44	1.17	1.40
Crates	-	1.11	0.71	0.20

The modules, which are stacked in pairs, were labeled alphabetically (Figure 2) and the crates within the modules were numbered (Figure 3). For cold weather transportation (winter, early spring and late fall), both tarps on the trailer unit were lowered (Figure 4) and vents running midline through the roof of the trailer (Figure 5) were adjusted according to ambient conditions to provide air circulation. Under warmer conditions, either one or both tarps were raised, and in summer, vents on the front and rear of the trailer (Figure 6) were occasionally opened.

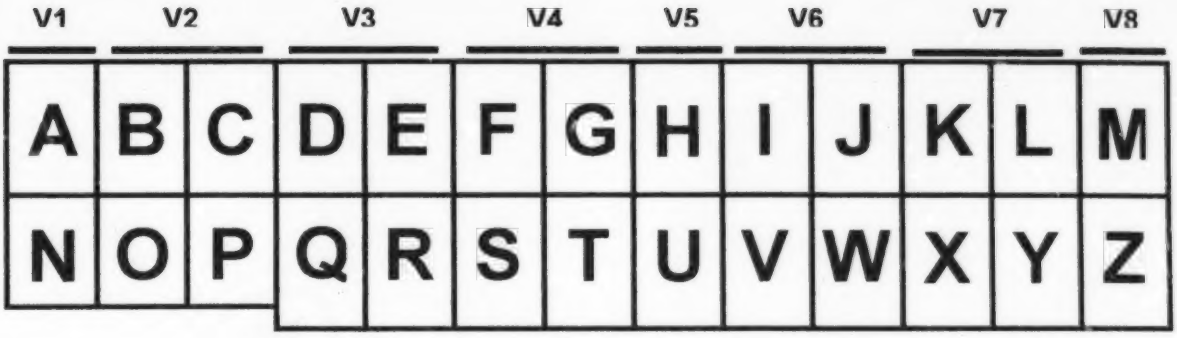

Figure 2. This drawing represents the side view of a transportation trailer used in Saskatchewan. Modules are labeled alphabetically. Horizontal bars above the drawing indicate the location of roof vents. Loggers were placed in 5 evenly distributed stacks of modules, represented by the red letters: A/N, D/Q, G/T, J/W and M/Z.

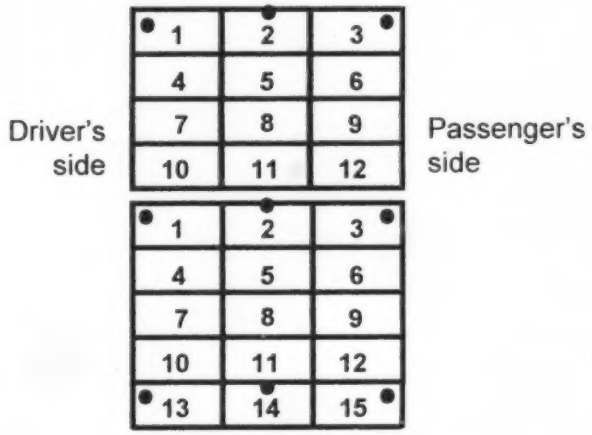

Figure 3. Crates within each module are numbered. When viewing the stack of modules from the rear of the trailer, crate 1 was located on the driver's side of the vehicle. The dots demonstrate logger placement. Within a stack of two modules, data loggers were placed in three rows of crates: the top row of both the top module (nearest the ROOF) and bottom module (CENTRE of the stack), as well as in the bottom row of the bottom module (nearest the FLOOR).

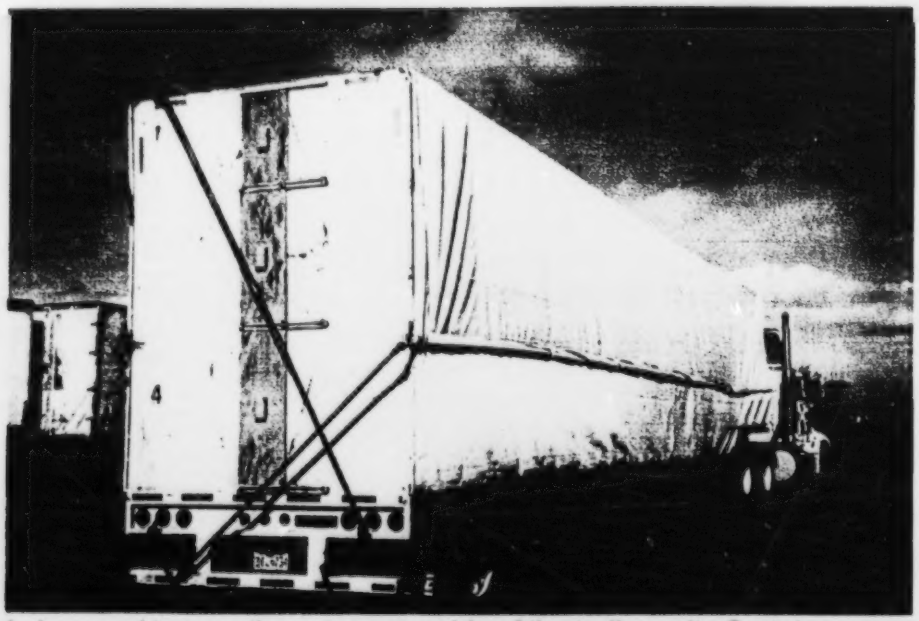

Figure 4. Lowered tarp on the passenger side of the trailer unit. Curtains are secured to the floor of the trailer with a continuous bungee cord and a metal rod running the length of the trailer. The tarps are not fastened to the headboard or rear of the trailer.

Figure 5. Vents running midline along the roof of the trailer are adjusted according to ambient conditions to provide air circulation. Latches are used to secure the vents.

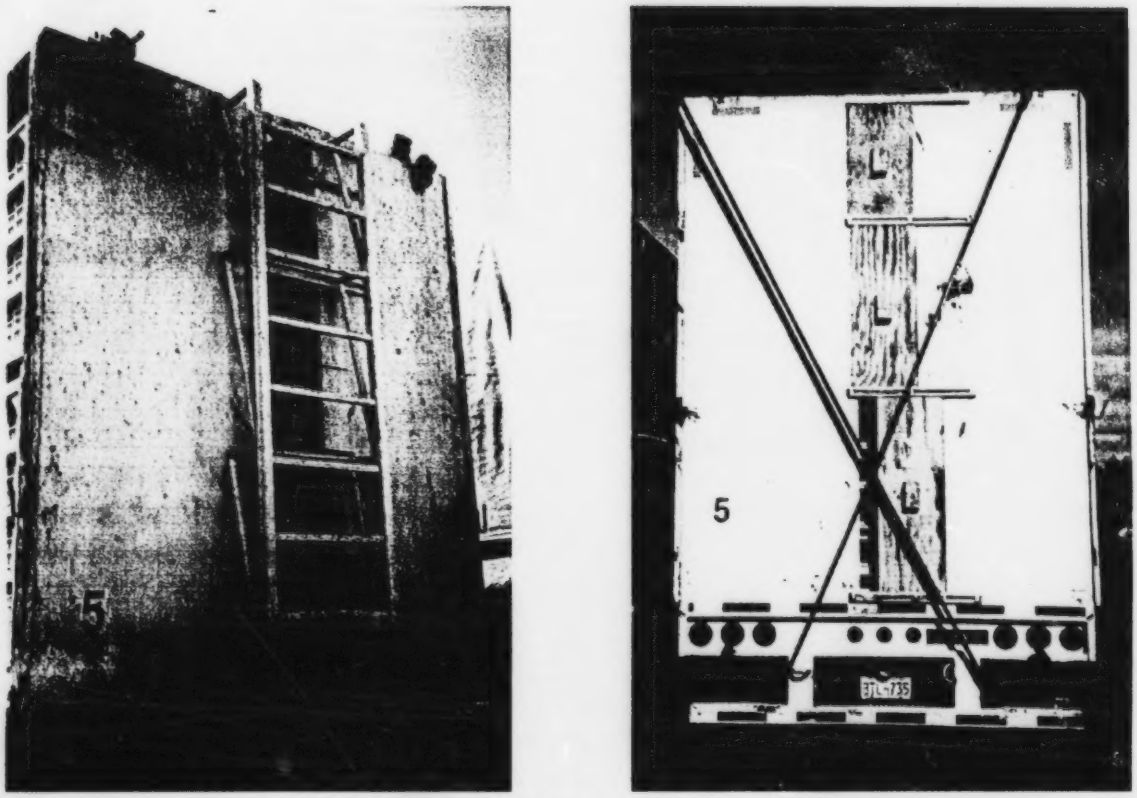

Figure 6. Front (left) and rear (right) vents on the trailers.

Preliminary study

A total of four preliminary broiler runs were initially monitored during the winter season to establish a basis for our subsequent research. These studies were completed with the support of Drs. Mitchell and Kettlewell from the UK. The primary focus of this research was on temperature and humidity, and continuous monitoring of these conditions was achieved using Gemini data loggers. The data loggers were programmed to record data at 72-sec intervals and placed into transport modules to assist in identifying extreme environmental conditions on the vehicle. Rectal temperatures (4 modules/trip, 10 birds/module) were recorded before and after transportation. An electronic temperature probe was placed three cm into the bird's cloaca until the temperature recording stabilized. In addition, sentinel birds were implanted with devices to continually monitor deep body temperature. (Kettlewell et al., 1997). Three sentinel birds were placed in each of two selected modules. Data loggers and implanted birds were placed in specified crates as the modules were loaded on the trailer at the broiler farm and retrieved at the processing plant in Wynyard, Saskatchewan immediately upon arrival.

Principal study

The primary focus of this research was to quantify temperature and humidity conditions imposed on broilers during transportation through continuous monitoring with Flashlink data loggers (DeltaTRAK, Pleasanton, CA, 94566, USA). The loggers were calibrated by the manufacturer and programmed to record data at a frequency of one reading per minute. The internal temperature sensor range was –40 to 66°C (accuracy ±1°C) while the humidity sensor range was 10 to 99% RH with an accuracy of ±5%. A total of 27 trips were monitored.

Commercial broiler farms cooperating in this study were located approximately 2 to 3 hours from the slaughtering plant. The research protocol was for the investigating team to arrive at the farm prior to loading so that the barn environment and bird condition could be evaluated. One member of the research team assessed litter moisture, atmospheric ammonia, and flock condition. Litter moisture was subjectively evaluated according to areas of caking, feed spillage, depth of coverage and moisture, and recorded as good, average or poor. Additionally two litter samples, one from the main floor and one within close proximity to the drinkers, were for litter moisture analysis from 13 barns. Each litter sample was composed of ten sub-samples gathered from evenly spread areas of the barn. The drinker sub-samples were taken within 15 cm of the water lines and the main floor sub-samples were collected at least 0.5 m away from any drinker, feeder, heat source, doorway or component of the ventilation system. Samples were sealed in a labeled zip-lock bag and frozen until moisture analysis was performed. Litter samples were prepared for moisture analysis by placing the samples into pre-weighed paper bags, re-weighing the bag and drying the sample at 55°C until no change in sample weight was noted (24-72 hours). Subsequently, the litter samples were analyzed for hygroscopic moisture (AOAC, 1990). Atmospheric ammonia was determined using a Drager apparatus. One reading was taken from the middle of each barn at bird level, avoiding areas in close proximity to any component of the ventilation system. A visual assessment of bird condition was made based on uniformity, leg problems, cull birds, feathering appearance and texture, and dead birds that may have been lying on the litter. Five lots of ten birds were evaluated throughout the barn to give an indication of the overall barn situation and were summarized as good, average or poor.

Five evenly distributed stacks of modules (Figure 2) were each equipped with nine data loggers recording the temperature and relative humidity of the microenvironment at one-minute intervals. In one stack of modules, three loggers were placed in each of the top, middle and bottom rows of crates during the loading procedure (Figure 3). In each of these rows, loggers were positioned at bird level in the centre of the middle crate and at the extreme edges of the outside crates. After loading, the transport vehicle was then followed to Wynyard where the trailer unit was driven into the live receiving area. Modules were immediately removed from the trailer and each crate was inspected. Bird condition was assessed, data loggers were retrieved, and dead birds (DOA - dead on arrival) were removed and identified for necropsy, which was completed by Drs. B. Althouse, D.S. Derow and L. Belanger of the Canadian Food Inspection Agency. Birds from the studies

were generally processed first thing in the morning. After processing, the plant reports were obtained for additional information, including the number of birds that died during the lairage period (DOS – dead on shackling).

Statistics

The MEANS procedure of SAS was used to calculate mean crate temperature and mean temperature lift and the corresponding standard deviation and range of values. All regression analyses were performed in Microsoft Excel. R-square values indicate the degree of correlation between variables. The GLM procedure of SAS was used to analyse DOA and DOS percentages according to ambient temperature and journey length. Duncan's Multiple Range Test was applied to separate significantly different means ($P<0.05$).

4. Results and Discussion

Preliminary study

In our initial studies, four broiler transport trailers were monitored under different external temperatures and journey duration. Pre-selected modules were equipped with data loggers (placed in either crates 2 or 5 of the module, see Figure 3) recording temperature and humidity of the microenvironment. Temperature heterogeneity was found among modules on all loads with temperatures ranging from 11 to 32°C, 10 to 28°C, 2 to 26°C and –1 to16°C for transportation times of 191, 193, 182, and 18 min and ambient temperatures of -7, -27, -28 and –18°C, respectively. The temperature ranges found on transport trailers are shown in Figures 7 to 10. The results demonstrated the potential for cold stress near air entry points and heat stress in poorly ventilated areas. Because the data loggers were not placed near the extreme outside of the trailer, it is probable that birds were exposed to colder temperatures than outlined above. Therefore, it was deemed essential to acquire a more complete picture of the temperature variability in subsequent research. Despite the low external temperatures, low levels of passive ventilation resulted in temperature lifts (internal temperature minus ambient temperature) ranging from 18-55°C. Although data loggers for humidity became saturated, wet birds, condensation and frost provided evidence of moisture accumulation during transportation. Broilers were able to maintain normal body temperatures during transportation with only minor indications of hypo- or hyperthermia. Because body temperature was labour intensive to collect and did not show major changes, it was decided not to monitor this parameter in the succeeding portion of the transportation study.

Data from the initial runs demonstrated that passive ventilation on tightly tarped transport trailers, while allowing birds to maintain body temperature, produced a heterogeneous distribution of airflow and consequently less than optimum temperate and humidity conditions. Based on these results, subsequent data collection focused on a comprehensive evaluation of temperature and relative humidity on transport vehicles under a wide range of environmental conditions.

Conclusions

- Broilers located in the core of the trailer unit adjusted to the thermal conditions, showing minor indications of hyperthermia or hypothermia. However, observations of wet birds and frost accumulation on the crates and modules suggested birds in locations outside the core were exposed to more adverse conditions.
- The air flow distribution pattern on broiler transportation trailer is complex, and resulted in thermal heterogeneity and compromising transport conditions which include:
  - Paradoxical heat stress due to the tightly tarped trailers
  - Non-planned air entry into the trailer
  - The potential for cold stress near air inlets

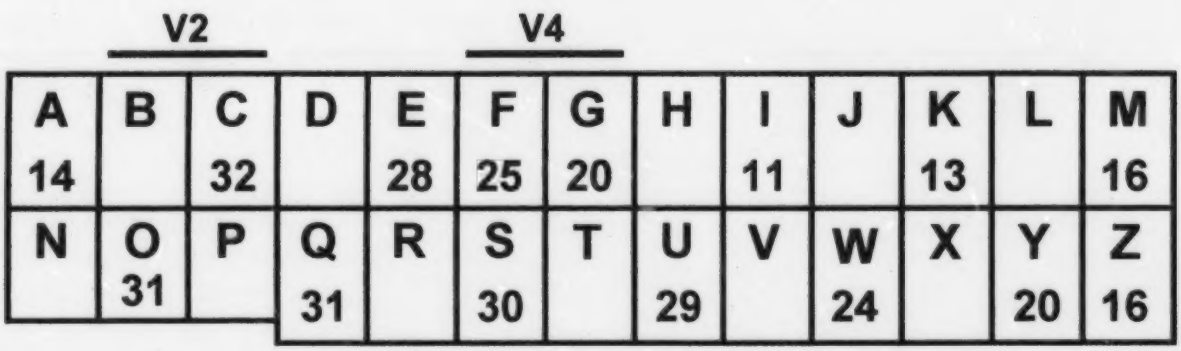

Figure 7. Average crate temperatures from the first preliminary journey. Ambient temperature was -7°C, roof vents 2 and 4 were open and the journey lasted 191 min. Data loggers were located in crate 5. Average temperature range was 11 to 32°C, creating a range in average temperature lift of 18 to 39°C. Module C recorded the highest average temperature, whereas module I recorded the lowest average temperature.

V4

A	B	C	D	E	F	G	H	I	J	K	L	M
24		25		28		22		10		15		12
N	O	P	Q	R	S	T	U	V	W	X	Y	Z
	21		27		27		26		23		20	

Figure 8. Average crate temperatures from the second preliminary journey. Ambient temperature was -27°C, only roof vent 4 was open and the journey duration was 193 min. Data loggers were located in crate 2. Average temperature range was 10 to 28°C, creating a range in average temperature lift of 37 to 55°C. The hot spot was module E and the cold spot was again in module I.

V4

A	B	C	D	E	F	G	H	I	J	K	L	M
19	26	25	24	22	18	12	7	4		2		3
N	O	P	Q	R	S	T	U	V	W	X	Y	Z
13		22	25		21		16		11		8	

Figure 9. Average crate temperatures from the third preliminary journey. Ambient temperature was -28°C, only the 4th roof vent was open and the journey duration was 182 min. Data loggers were located in crate 2. Mean crate temperatures ranged from 2 to 26°C, with a corresponding range in average temperature lift of 30 to 54°C. The highest mean temperature occurred in module B and the lowest mean temperature was in module K.

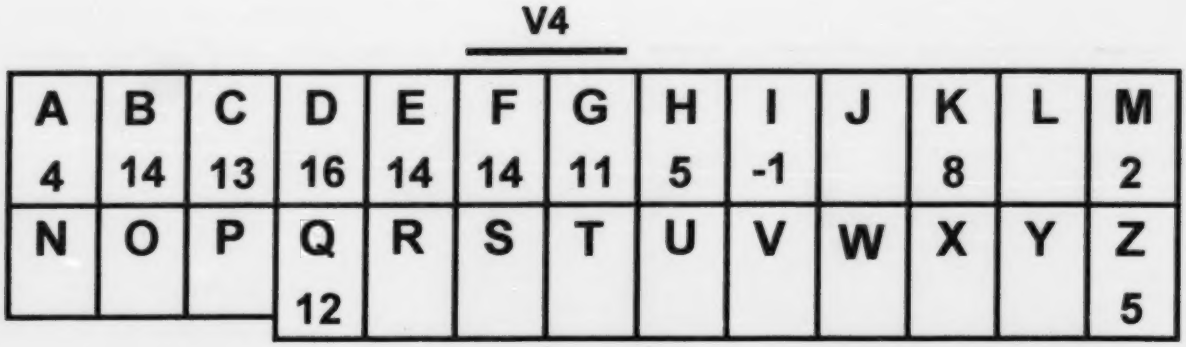

Figure 10. Average crate temperatures from the fourth preliminary journey. Ambient temperature was -18°C, the 4th roof vent was open and the journey length was only 18 min. Data loggers were located in crate 2. Mean crate temperatures ranged from -1 to 16°C, with a corresponding range in average temperature lift of 17 to 34°C. The highest temperature occurred in module D and the lowest temperature was in module I. The short transit period did not permit the development of the thermal core evident in the preceding journeys.

Principal study

Description of transport journeys

A total of 27 trips was studied in the principal portion of this research and is summarized in Table 2. Reported data included journey length, ambient temperature, mean temperature and range of temperatures in monitored crates, and the corresponding mean temperature lift values. The temperature values are averages for the whole trip and do not take into account any changes in vent configuration that might have occurred during the trips. Journey length varied from 140 to 240 minutes. The range of ambient temperatures was –27.2°C to 21.9°C. For all trips below the ambient temperature of 7.2°C, the tarps on the transport vehicle were lowered and secured on both sides and a variable number of roof vents was opened. At or above 7.2°C, one or both tarps were raised to provide increased ventilation, all roof vents were open, and front and rear vents were occasionally open at higher temperatures.

As expected, ambient temperature affected the mean crate temperatures on the transport vehicle (Figure 11). The linear relationship between ambient temperature and mean temperature of the crates was stronger when the tarps were raised ($r^2 = 0.91$; $y = 0.69x + 8.54$) in comparison to when they were lowered ($r^2 = 0.64$; $y = 0.35x + 11.29$). This is a reflection of the variable vent configuration and the impact of imperfect sealing of the tarps at the lower temperatures, in contrast to the more uniform and unrestrictive ventilation configurations at higher temperatures.

TABLE 2. An overall summary of journeys ranked according to mean ambient temperature

Journey length (min)	Ambient temp. (°C)	Crate temperature		Temperature lift[1]	
		Mean (°C)	Range (°C)	Mean (°C)	Range (°C)
190	-27.2	8.1	-9.8 to 26.2	35.3	17.4 to 53.4
155	-20.7	0.9	-10.3 to 25.4	24.5	10.4 to 46.1
190	-20.6	3.8	-13.7 to 20.9	21.5	6.9 to 41.5
190	-12.9	4.1	-6.8 to 20.6	17.0	6.1 to 33.5
150	-12.7	5.4	-4.3 to 18.3	18.1	8.4 to 31.0
170	-10.5	6.7	-4.3 to 19.4	17.2	6.2 to 29.9
185	-9.7	6.2	-4.3 to 21.1	15.9	5.4 to 30.8
240	-9.1	9.3	-1.7 to 25.6	18.4	7.4 to 34.7
155	-6.6	6.1	-1.8 to 18.4	12.7	4.8 to 25.0
165	-5.8	9.4	0.5 to 22.6	15.2	6.3 to 28.4
145	-5.0	8.6	0.2 to 22.1	13.6	5.2 to 27.1
170	-0.9	11.4	2.7 to 24.8	12.3	3.6 to 25.7
180	-0.1	11.5	4.2 to 22.1	11.6	4.3 to 22.2
200	2.8	14.3	7.6 to 24.9	11.5	4.8 to 22.1
165	2.8	14.0	6.5 to 24.3	11.2	3.7 to 21.5
175	2.9	13.9	6.4 to 23.9	11.0	3.5 to 21.0
155	7.2	12.6	8.6 to 18.8	4.3	1.4 to 11.6
205	7.9	15.9	11.1 to 23.3	8.0	3.2 to 15.4
165	11.8	17.1	12.8 to 21.6	5.3	1.0 to 9.8
205	12.4	17.3	14.0 to 22.4	4.9	1.6 to 10.0
190	12.8	16.6	14.1 to 21.0	3.8	1.3 to 8.2
195	13.5	17.6	15.0 to 21.2	4.1	1.5 to 7.7
160	14.8	18.1	15.7 to 21.5	3.3	0.9 to 6.7
160	14.9	17.9	15.7 to 21.4	3.0	0.8 to 6.5
180	17.5	21.8	18.6 to 24.7	4.3	1.1 to 7.2
140	17.7	20.5	18.4 to 23.6	2.8	0.7 to 5.9
175	21.9	24.2	22.4 to 26.8	2.3	0.5 to 4.9

[1] Temperature lift = crate temperature – ambient temperature.

Mean temperature lift was calculated as the difference between mean ambient temperature and mean crate temperature. In the coldest journey conducted, mean temperature lift was 35.3°C with a range of 17.4 to 53.4°C; whereas the average temperature lift from the warmest study performed was 2.3°C with a range of 0.5 to 4.9°C (Table 2). These data demonstrate that at higher ambient temperatures with both tarps raised there was less thermal variation throughout the trailer as compared to studies conducted under colder conditions with both tarps lowered.

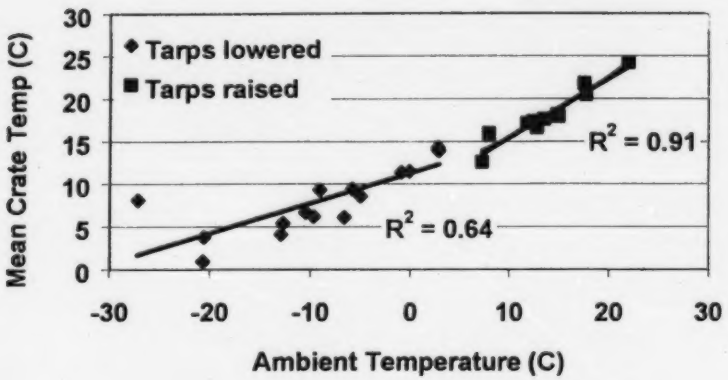

Figure 11. Linear relationship between ambient temperature (°C) and mean crate temperature over the entire trailer (°C) for trips conducted with both tarps raised or both tarps lowered.

Temperature stability during journeys

Selection of environmental data for analysis was based on the finding that the temperature conditions stabilized during transportation, usually within 20 minutes of departure from the broiler farm. An example of the crate temperatures recorded by loggers during a warm weather trip is shown in Figure 12. Values were taken from the row of crates nearest the roof in module D. In the first 15 minutes, temperatures in all three crates decreased as the heat accumulated during loading was dissipated with vehicle movement. The increase and decrease in temperature following the initial 15-minute period suggests that the temperature does not stabilize. However, if the change in ambient temperature is examined (Figure 13), it becomes obvious that the crate temperatures are reflecting shifts in the ambient conditions.

The finding that temperatures stabilized also permitted the collection of more data, as two ventilation configurations (roof vent, curtain or front and rear vent) could be tested in the same trip. Following a 30-minute stabilization period for each configuration, mean crate temperatures were calculated by taking the average of the subsequent 15 temperature recordings, thus creating a 15-minute data period. An example of the stabilization and data periods from a cold weather trip is shown in Figure 14. Values from the 15-minute data periods are utilized in the succeeding graphs.

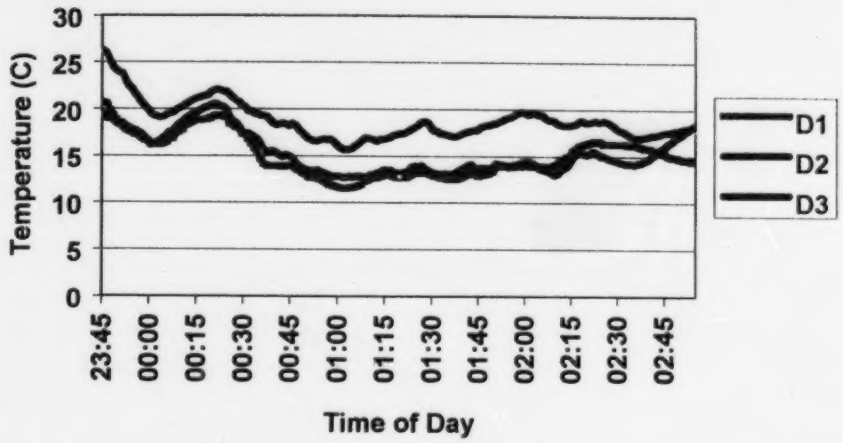

Figure 12. Crate temperatures (°C) from module D recorded by data loggers for the duration of a warm weather journey. Crate D2 is located in the middle of crates D1 and D3. Temperatures initially decline as vehicle movement dissipates accrued heat. Crate temperatures reflect changes in the ambient temperature.

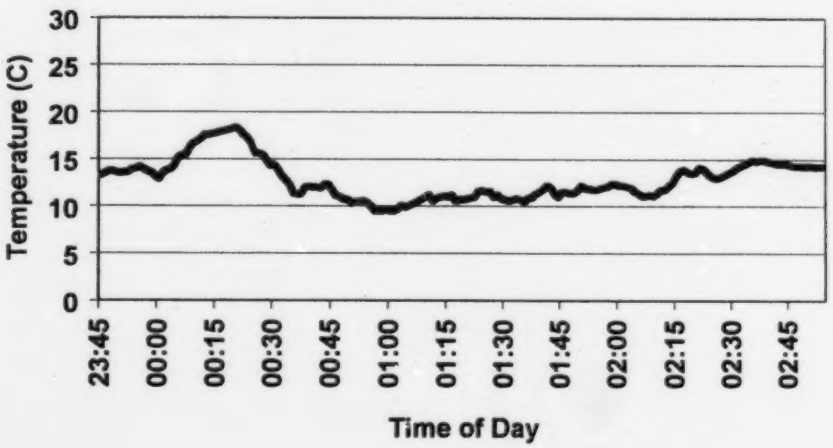

Figure 13. Ambient temperature (°C) from the warm weather journey that the crate temperatures in Figure 12 were extracted. Crate temperatures mimic changes in the ambient temperature.

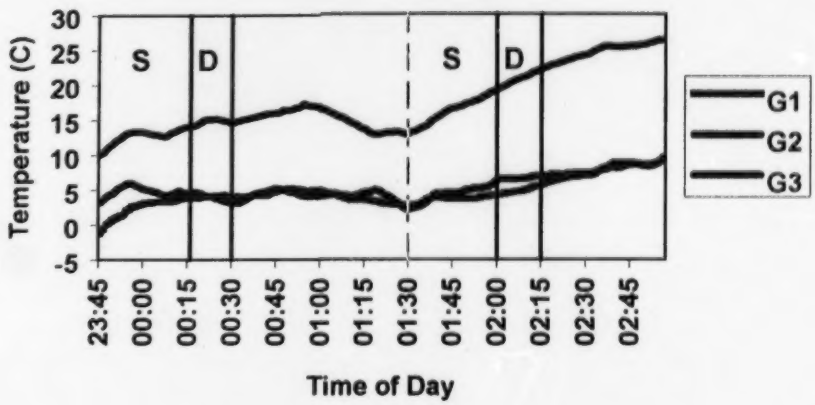

Figure 14. Thirty-minute stabilization (S) and 15-minute data (D) periods from two vent configurations during a cold weather trip. The dashed green line indicates when the vent change occurred. Values from the 15-minute data periods are utilized in the succeeding graphs.

Pressure distribution and air flow

The airflow inside the trailer is governed by two factors: the pressure distribution on the outside surface of the trailer and the dense packing inside the trailer. The pressure distribution over the surface of the trailer is characteristic of blunt, sharp-edged bodies (Figure 15). The headboard of the trailer has a positive pressure that is highest near the top leading edge of the trailer and decreases down the headboard. Therefore, an opening in the headboard will act as an air inlet. Flow separation occurs at the leading edge of the top of the trailer and at the leading edges of the sides of the trailer, and causes large negative pressures on the top and sides of the trailer near the front. The negative pressure on the top and sides of the trailer declines towards the back of the trailer. The largest negative pressure occurs on the top of the trailer near the front. Therefore, vents open near the front of the trailer will act as exhaust outlets for the trailer and openings at the rear of the trailer will act as air inlets. The dense packing inside the trailer causes a significant obstruction to air movement within the load and limits air mixing within the trailer. With the tarps down, air may short circuit between vents on the roof or between openings at the bottom of the tarp and vents in the roof directly above. This basic description of the pressure distribution on the outside surface of the trailer and the dense packing inside the trailer are useful in interpreting the environmental data collected in this research.

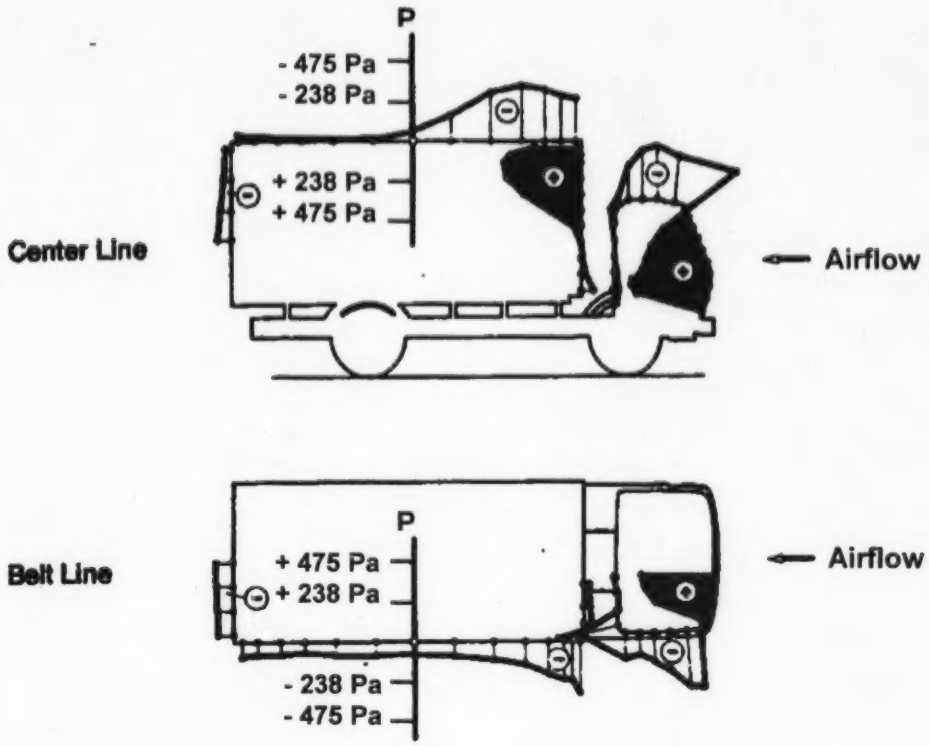

Figure 15. Pressure distributions on the cab and body of a typical truck traveling at 100 km/h. Air flows from low-pressure areas to high-pressure areas, generally taking the most direct route (adopted from Götz, 1987).

In-crate temperature conditions – effect of ambient temperature, and vent and curtain configuration

Broiler transportation journeys were sorted according to ambient temperature, vent configuration and tarp arrangement. Temperature group one (T1) consisted of trips performed in temperatures below -16°C. Temperature groups two (T2), three (T3), four (T4) and five (T5) were performed in the temperature ranges –15.9°C to -6°C, -5.9°C to +5.9°C, 6°C to 15.9°C and above 16°C, respectively.

Through all journeys conducted in T1, T2 and T3, both trailer tarps were lowered and the front and rear vents were closed. The eight vents along the roof of the trailer were the only vents manipulated in these temperature categories. In T4, all eight roof vents were open and the front and rear vents remained closed; however, tarping strategy was adjusted. Generally both tarps were raised and all roof vents were open during transportation in warm weather (T5). The front and rear vents were occasionally opened and when required (during rainfall), one of the tarps was lowered.

All figures describing the effect of ambient temperature, and vent and curtain configuration on in-crate temperatures follow an identical format. Temperature (°C) is displayed on the Y-axis and stack location is on the X-axis. The front stack location corresponds to modules A/N, followed by stacks D/Q, G/T (middle stack location), J/W and M/Z (back stack location). In each figure set, figure a) represents crate temperatures from the top row of crates in a stack and is identified as ROOF (i.e. crates A1, A2, A3 from the front stack location); figure b) denotes crate temperatures from the middle row of crates in a stack and is labeled CENTRE (i.e. crates N1, N2, N3 from the front stack location); and figure c) depicts crate temperatures from the bottom row of crates and is named FLOOR (i.e. crates N10, N11, N12 from the front stack location). Blue bars identify crates on the driver side of the trailer ; whereas burgundy and beige shaded bars represent crates in the middle and the passenger side of the trailer, respectively.

It needs to be emphasized that the temperature and humidity conditions measured in this study will not reflect the conditions for the entire crate and therefore the conditions imposed on all birds. For example, the data loggers placed in the driver and passenger side crates were located at the outside edge of the crate and exposed to the most adverse conditions. Bird density, and crowding within the crate will influence the microenvironment birds experience.

Figures 17 to 34 are found in Appendix A.

Some general trends were obvious for most trips. Within a row of crates, the middle crate was warmer than those from the driver and passenger sides of the trailer. With minor exceptions, crate temperatures on the driver and passenger side of the vehicle from the same row of crates are comparable.

Adjustment of roof vents

Vents along the roof of the trailer were adjusted for trips monitored below 6°C (T1, T2 and T3). Open vent area affected temperature lift and the summarized data are shown in Table 3. As open vent area increased from 0.18 m^2 to 2.0 m^2, there was a strong negative relationship between vent area and temperature lift; but once the vent area exceeded 2.0 m^2, the degree of temperature lift plateaued (Figure 16). This information indicates that air exchange can be controlled somewhat by the area of vent opening, particularly when adjustments are made to the front vents.

TABLE 3. Effect of roof vent opening on crate temperature and temperature lift during trips when ambient temperature was below 6°C

Vent opening		Crate temperature (°C)				Temperature lift (°C)			
Vent ID	Area m^2	Mean	SD[1]	Min.[1]	Max.[1]	Mean	SD	Min.	Max.
5/2[2]	0.18	6.7	7.7	-7.4	22.2	29.6	7.7	15.5	45.1
1	0.29	3.2	9.5	-14.8	27.6	21.7	10.0	4.2	49.2
1,5	0.64	1.8	8.9	-13.5	23.2	22.5	8.9	7.0	44.1
1,2	0.86	7.6	6.6	-5.5	22.5	17.6	6.7	5.0	31.7
1,5,8	0.93	4.5	6.5	-4.6	17.7	16.0	6.5	6.9	29.2
1,2,5, 6	1.78	10.8	6.5	-0.3	24.9	14.3	6.6	3.7	30.7
1-4	2.00	13.0	6.2	2.4	26.4	10.0	6.2	-0.6	23.4
1-6	2.92	13.9	6.0	4.6	26.5	10.9	6.0	1.6	23.5
1-8	3.78	11.6	6.4	-4.8	27.3	12.6	5.8	1.4	28.4

[1] SD = standard deviation; Min. = minimum; Max. = maximum.
[2] Vents 1 and 8 were 1.22 m x 0.235 m; vents 2, 3, 4, 6 and 7 were 2.43 m x 0.235 m; vent 5 was 1.50 m x 0.235 m; 5/2 designates that only the back half of the 5th vent was open.

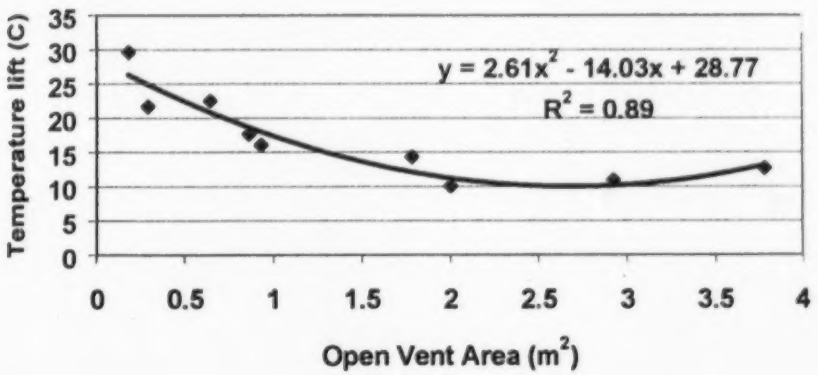

Figure 16. Relationship between mean temperature lift (°C) and open vent area (m^2) when journeys are conducted with both curtains lowered.

Temperature group 1 (<-16°C)

A total of three trips were monitored in this temperature range. On two occasions, vents 1 and 5 were initially open and the fifth vent was closed midway through the trip, leaving only the first vent open. The third trip was conducted with the back half of the fifth vent open and all remaining roof vents closed. No changes in vent configuration were incorporated into the trip. Several general observations can be made from the data:

- Air was exhausted from the trailers through the roof vents.
- Temperatures at the floor of the trailer for all stack locations were very low, as were the back of the trailer (roof, centre, floor). The tarps used for the sides of the trailers are difficult to seal in these areas and as a consequence very cold air infiltrates the load. The acceptability of these temperatures will be discussed later.
- As seen in the preliminary study, the highest temperatures were found in the middle and upper front sections of the trailer. This is due to the distance from areas of air infiltration and the natural forward movement of air on the load.

Information can also be obtained from comparing the vent configurations:

Vents 1 and 5 open (Figure 17, 2 replications)

- Temperatures at the centre and floor of the front stack indicate that air is being drawn through this area, likely through a warped bottom vent on the headboard.

Vent 1 open (Figure 18, 2 replications)

- Changing the vent configuration from roof vents 1 and 5 open to only vent 1 open increased the temperature near the roof and centre of the stacks, but negatively influenced the crate temperatures closest to the trailer floor. Air may be short-circuiting at the front stack location or in other words, is being drawn in from below the tarps and exiting straight up, through the open vent.
- Lower temperatures on the passenger side of the front stack indicated inadequate tarping compared to the driver side of the same location.

Vent 5 open (Figure 19, no replication)

- A different trailer was used in this trip in comparison to that used for the preceding vent configurations.
- In comparison to the other vent configurations, warmer temperatures were recorded in roof and centre crates. The smaller vent opening (0.18 vs. 0.29 m^2) and the more posterior location of the vent (less negative pressure, see Figure 15) likely resulted in reduced airflow through the trailer and higher temperatures.
- Crate temperatures across the roof decrease towards the rear of the trailer. This could imply that air entered from the rear of the trailer and exited through the fifth vent.
- The temperatures at the centre of the stack follow the same trend with the exception of the first stack. The difference in the first stack location would suggest that the front vents on this trailer were relatively well sealed.
- Cold temperatures at the floor of the middle stack suggest air is entering at this location and being drawn straight up towards the open vent along the roof. This is another example of air taking the most direct path from air entry to air exhaust.

Temperature group 2 (–15.9°C to -6.0°C)

Five trips were monitored in this temperature range and again because of changing vents mid way through the trip, several vent configurations were studied. General observations included:

- Roof vents may be acting as points of air entry and exit.
- As vent area increased, roof temperatures became more variable
- Temperatures along the trailer floor decreased when vent area was reduced.

Information obtained from comparing the vent configurations included:

Vents 1 to 8 open (Figure 20, 2 replications)

- Variable temperatures across the roof of the trailer indicated that air entered and exited in an uncontrolled manner.
- The only areas experiencing temperatures below 0°C were the driver and passenger crates in the middle roof location and the passenger side crate nearest the trailer floor in the last stack.

Vents 1 and 2 open (Figure 21, 4 replications)

- The floor area of the front two stacks became colder once the back vents were closed which suggested increased air flow through this area
- Decreased temperatures in the roof of the second and third stacks support the concept of coincidal air inlet and outlet vent areas.

Vents 1, 5 and 8 open (Figure 22, no replication)

- Temperatures at the roof of the last two stacks indicated opening the rear vent along the roof allowed cold air to enter through the rear of the trailer and exit directly through the eighth roof vent
- Again temperatures in the first stack, at the centre and floor locations, imply air entry from the headboard vents
- Trailer floor conditions are cold.

Vent 1 open (Figure 23, no replication)

- Colder temperatures throughout the front stack suggest air is entering at the trailer floor and being drawn straight up, towards the open vent.
- Temperatures at the floor of the trailer for all stack locations as well as the back of the trailer (roof, centre, floor) remained low, with the exception of the middle crate nearest the roof.
- Cold temperatures in the first stack, at the centre and floor locations, suggest air is entering from the headboard vents

Temperature group 3 (–5.9°C to +5.9°C)

The following vent configurations were tested in this temperature range: all vents (1-8) open (Figure 24, 3 replications), vents 1 to 6 open (Figure 25, 2 replications), vents 1 to 4 open (Figure 26, 2 replications), and vents 1, 2, 5 and 6 open (Figure 27, 2 replications). In this moderate temperature range, all crate temperatures were above 0°C irrespective of

the vent configuration and it is unlikely that low temperature would have an overly adverse effect on broiler chickens. The highest temperatures approached but did not exceed 26°C. With minor exceptions, temperature trends indicated that airflow was relatively uniform from the rear to front of the trailer.

Adjustment of tarps, and front and rear vents

The degree of temperature lift was affected by tarp configuration and the data summarized for trips monitored above 6°C (T4 and T5) are shown in Table 4. The degree of air exchange in the trailer is directly related to tarp configuration with mean temperature lifts of 3.3, 5.7 and 9.6°C for both tarps raised, one tarp raised and both tarps lowered, respectively. Possibly more important than the mean temperature lift is the maximum temperature lift, which provides guidance regarding the potential for dangerously high temperature. These data are useful for establishing a strategy for tarp adjustment practices in warmer weather.

With tarps raised, closed or open front and rear vent configuration had little effect on the mean crate temperature (18.9°C and 18.6°C, respectively) and mean temperature lift values (3.3°C and 2.9°C, respectively).

TABLE 4. Effect of tarp positioning and front and rear vent status on crate temperature and temperature lift during trips where ambient temperature was above 6°C

		Crate temperature (°C)				Temperature lift (°C)			
Tarp[1]	FRV[2]	Mean	SD[3]	Min.[3]	Max.[3]	Mean	SD	Min.	Max.
DD	C	17.2	4.0	11.0	25.3	9.6	4.0	3.4	17.7
UU	C	18.9	4.5	6.9	28.2	3.3	2.0	0	11.4
UU	O	18.6	3.9	12.2	27.0	2.9	2.0	0	8.9
DU	C	17.4	2.8	12.1	24.2	5.8	2.9	1.3	13.9
UD	C	19.7	4.7	8.9	30.0	5.5	2.9	0.3	15.3

[1] Tarp configuration: DD – both lowered; UU – both raised; DU – driver side lowered, passenger side raised; UD - driver side raised, passenger side lowered.
[2] Front and rear vent configuration: C – closed; O – open.
[3] SD = standard deviation; Min. = minimum; Max. = maximum.

Temperature group 4 (6.0°C to 15.9°C)

In this temperature range, all eight roof vents were open and the front and rear vents remained closed; however, tarping strategy was adjusted. Tarp configurations included both tarps lowered (Figure 28, no replication), both tarps raised (Figure 29, 4 replications), or one tarp lowered (Figures 30 and 31, 2 and 3 replications for the driver tarp down and passenger tarp down, respectively). Crate temperatures recorded within this temperature range were all moderate and unlikely to cause a negative impact on bird well being.

Temperature group 5 (>16.0°C)

In general, both tarps were raised and all roof vents were open during transportation in this temperature group. The front and rear vents were closed (Figure 32, 5 replications) or open (Figure 33, 4 replications) and when required one of the tarps was lowered. This was the case for one trip where rainfall prompted the truck driver to lower the passenger side curtain (Figure 34, no replication). Crate temperatures in the monitored trips were uniform when both tarps were raised. Opening the front and rear trailer vents resulted in slightly cooler and more homogeneous temperatures, which would be advantageous during hot weather. Our results suggest that a moving trailer during dry summer conditions should for the most part provide a suitable transport environment. The data collected on temperature lift should allow the prediction of dangerous temperature conditions. Rain can become a problem during summer conditions because tarps may be lowered (one side only) to keep the birds dry. Closing one tarp resulted in higher crate temperatures, which approached a point where caution may be warranted. The highest mean crate temperature on this trip was 30°C. Drivers must be aware of the potential for lethal conditions when one tarp is down in summer conditions.

Relative humidity

In addition to temperature, data loggers recorded relative humidity, which contributes to the complex thermal environment within the trailer unit. Mitchell and Kettlewell (1998) characterized the temperature and relative humidity conditions from broiler transportation journeys carried out in the United Kingdom and simulated these conditions to investigate physiological stress responses in broilers. The concept of Apparent Equivalent Temperature (AET) was introduced and is considered to be an integrated index of the conditions broilers are exposed to during transportation. AET combines dry-bulb temperature and relative humidity to give an indication of the effective temperature, much like a wind-chill index. The temperature/humidity conditions representing AET values capable of inducing severe stress are represented by the solid line in Figure 35. Any temperature/humidity combination that lies above this line would be within the danger zone (D). The dashed line was incorporated into the figure based on results from complementary research. Combinations that fall between the dashed and solid lines are predicted to instigate moderate stress responses, and lie in the alert zone (A). Below the alert zone is a safe zone (S), which would present no risk to the birds. Unfortunately, the figure does not incorporate cold temperature/humidity combinations that are typically encountered during winter transportation in Saskatchewan. However, some assumptions can be made from additional information. A study conducted by Mitchell et al. (1997)

reported that if birds are wet during transportation, ambient temperatures as high as 6°C could trigger moderate hypothermia; therefore temperatures below 6°C could be classified as potentially dangerous (PD), particularly if the humidity was high or the birds were wet. Temperatures between 6°C and 15°C could be considered safe regardless of humidity.

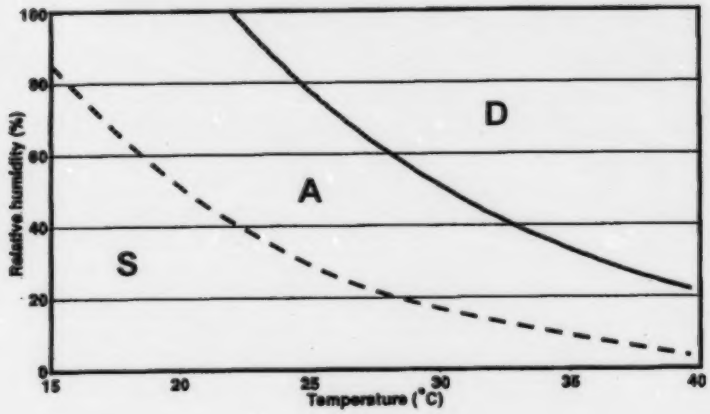

Figure 35. Dry-bulb temperature (°C) and relative humidity (%) combinations that yield AET values in the danger zone (D), alert zone (A) or safe zone (S).

From the individual journeys performed in the ambient temperature categories T3 to T5, mean relative humidity and temperature data for each crate were combined and the corresponding AET zone was recorded. The percentage of crates that fell within each AET zone was calculated and pooled according to ambient temperature classification (Table 5). During cold weather transportation (T1 and T2), loggers positioned near air inlets did not provide accurate results, as the humidity sensors could not function in the cold temperatures. Because the tarps were lowered during cold ambient conditions, moisture accumulated within the load and saturated the data loggers located in areas other than the inlets. AET zone classification for journeys completed in T1 and T2 was based on recorded crate temperatures and the assumption that RH ranged from 80% to 95%.

Ambient temperatures below -16°C showed the highest proportion (61.0%) of crates with potentially dangerous (PD) temperature-humidity combinations followed by those in the temperature ranges –15.9 to –6.0°C and –5.9 to +5.9°C (Table 5). This was expected in cold conditions as unintentional air inlets on trailer units with both tarps lowered allowed cold air to penetrate along the floor and back end of the trailer. Frost accumulation on birds located in these areas where air infiltrated was noted upon arrival at the processing plant and warrants concern. Ambient temperatures above 6°C did not have any crates

falling in the potentially dangerous zone. Due to the development of a thermal core, cold weather transportation resulted in 13.0% and 10.0% of crates classified in the alert zone when ambient temperatures were below -16°C and between –15.9 to –6.0°C, respectively; 23.7% and 39.0% of crates recorded safe zone conditions under the same ambient temperature classifications. As the ambient temperature approached 0°C, 78% of the crates fell within the safe zone. The moderate temperature range of 6.0 to 15.9°C had 85.0% of crates in the safe zone and the remaining fraction in the alert zone. As the ambient temperature extends beyond this range, a higher percentage of crates fall into the alert classification (Table 5). The greatest potential for the development of conditions that can induce severe stress responses in birds due to high temperature/humidity combinations lies within the two coldest temperature groups. The percentage of crates in the danger zone was 0.3% and 1.3% for ambient temperatures within –15.9 to –6.0°C and <-16°C, respectively. Lowered curtains restrict airflow distribution during cold weather transportation, providing the opportunity for high crate temperatures to develop in conjunction with high humidity levels in the core of the trailer. In addition, crates and modules do not dry completely after washing when stored outdoors. Therefore, water freezes to the containers and once birds are introduced they produce enough heat to melt the ice. This moisture may also contribute to the high humidity conditions encountered in cold weather transport. Observations of wet birds, particularly in the middle of the modules and core of the trailer, suggests that the moisture produced from bird respiration and the low ventilation rate are the primary factors responsible for the high humidity conditions in the core of the trailer.

TABLE 5. The effect of ambient temperature on apparent equivalent temperature (AET) zone classification

Ambient temperature	AET zone classification (%)			
	PD[1]	S[2]	A[3]	D[4]
< -16.0°C	61.0	23.7	13.0	1.3
-15.9°C to –6.0°C	51.8	39.0	10.0	0.3
-5.9°C to 5.9°C	15.4	78.4	5.86	-
6.0°C to 15.9°C	-	85.0	15.0	-
>16.0°C	-	56.3	43.7	-

[1]PD= potentially dangerous zone, crate temperatures below 6°C.
[2]S=safe zone, no risk to birds.
[3]A=alert zone, moderate stress responses.
[4]D=dangerous zone, severe stress responses.

High ambient temperatures during transportation may be hazardous when the passively ventilated vehicles are stationary, as the heat and moisture produced by the birds is not effectively dissipated. During warm weather transportation, observations of panting birds were made upon arrival at the processing plant after the trailer had been stationary for several minutes. As the modules were examined for DOA birds, bird condition was very

dry so the likelihood of high temperature and high humidity conditions developing concurrently would require additional time.

Based on AET zone classification, transportation when ambient temperatures were above 6°C was least stressful for the birds. However, caution should be taken as ambient temperatures exceed 16.0°C due to the increased proportion of crates in the alert zone. If the trailer units remain stationary, the potential for hazardously high crate temperature and humidity combinations exists. Below 6.0°C, the potential for dangerously cold conditions increased due to the cold air entering around the edges of the lowered tarps and would be compounded further if the contribution of air speed were considered. As well, lowering the tarps reduced airflow within the trailer, leading to high temperature and humidity conditions in the trailer core likely to cause severe stress responses in birds from this location. Lairage must provide appropriate environmental conditions in both summer and winter to avoid broiler stress and death loss (see *Dead on arrival*).

Dead on arrival

The level of death loss during 26 monitored trips was very low with a mean of 0.11% and a range of 0.05 to 0.52% (Table 6). These values, associated with bird death occurring during the transportation period only, are lower than the Canadian average for 2000 (0.40%) and the average value found in a study from the UK (0.22%). However, the DOA data from this research did not include death losses occurring during the holding period prior to processing.

The necropsy results for these birds are shown in Table 7. The causes have been grouped according to our judgment of the most important factor contributing to the death. These include transportation itself, catching trauma, farm-related death, death as a result of our data collection and other reasons not readily associated. It must be emphasized that transportation may have contributed to death occurring in all categories but that other factors made the birds susceptible to dying. Birds with no visible lesions represented 34% of the DOA birds and are likely associated with transport. Although the exact reason for death can't be established because of the lack of symptoms, it is likely that at least some of these birds died of acute heart failure (sudden death syndrome). The next category is associated with catching trauma and accounted for 29.2% of the birds dying in transit. The condition of birds on-farm, prior to loading, can have an important impact on their ability to withstand the stressors of transportation. Ascites is a chronic form of heart disease that is affected by bird management and barn environmental conditions. Similarly, cyanosis is associated with chronic heart failure (Olkowski, personal communication). Several birds were noted to be emaciated upon necropsy or were culled at the slaughtering plant after being classified as runts. Again these characteristics are related to the grow-out period and not transportation. The final farm associated cause of death was categorized as infectious disease which would have been underway prior to bird marketing. For a small number of birds (1.4% of DOA), no obvious association was noted.

TABLE 6. Death loss immediately after transportation and at the time birds were shackled for slaughter

Journey length (min)	Ambient temp. (°C)	DOA[1] (%)	DOS[2] (%)
190	-27.2	0.15	0.24
155	-20.7	0.52	0.90
190	-20.6	0.15	0.37
190	-12.9	0.17	0.25
150	-12.7	0.10	0.26
170	-10.5	NA[3]	NA
185	-9.7	0.05	0.31
240	-9.1	0.16	0.56
155	-6.6	0.11	0.20
165	-5.8	0.22	0.41
145	-5.0	0.15	0.17
170	-0.9	0.12	0.24
180	-0.1	0.12	0.13
200	2.8	0.09	0.19
165	2.8	0.12	0.20
175	2.9	0.08	0.11
155	7.2	0.11	0.23
205	7.9	0.09	0.13
165	11.8	0.13	0.28
205	12.4	0.17	0.39
190	12.8	0.10	0.12
195	13.5	0.12	0.19
160	14.8	0.09	0.28
160	14.9	0.16	0.32
180	17.5	0.09	0.23
140	17.7	0.13	0.21
175	21.9	0.11	0.25

[1] DOA – dead immediately upon arrival at the slaughtering plant.
[2] DOS – dead at shackling immediately prior to slaughter. Time in lairage ranged from 170 to 305 minutes (235 min average) after arrival at slaughtering plant.
[3] NA = not available.

TABLE 7. Necropsy findings from 26 trips for broilers found dead on arrival (DOA) immediately upon arrival at the slaughtering plant

Association[1]	Cause of death	# of birds	% of DOA[2]	% of DOA by association
Transportation	No visible lesions	97	34.0±3.4	34.0
Catching	Head trauma	66	23.2±3.4	29.6
	Dislocated hip	13	4.6±1.5	
	Liver hemorrhage	4	1.4±0.8	
	Broken bones (culls)	1	0.4±0.5	
Farm	Ascites	52	18.2±3.2	31.9
	Cyanosis	17	6.0±1.8	
	Emaciated	12	4.2±2.1	
	Infectious	10	3.5±1.6	
Experimental	Accidental[3]	9	3.2±1.9	3.2
Other		4	1.4±0.8	1.4
	TOTAL	285	100.0	

[1] Cause of death is sorted according to the factor that is considered to have the most impact on death loss.
[2] Mean ± the standard error of the mean.
[3] Death due to trauma during data collection.

Ambient temperature affected the incidence of birds dying during transport. When trips are grouped into five temperature categories as shown in Table 8, the incidence of DOA broilers was significantly higher when the ambient temperature was < -16°C. However, the three trips monitored under this temperature range showed considerable variability in the incidence of DOA (Table 9). Bird loss was 0.15% for two trips and 0.52% for the remaining trip. This suggests that factors such as farm management and specific management of the trailer units can affect this characteristic and that cold temperatures do not automatically translate to elevated death loss. The higher level of DOA was due to an increased incidence of ascites and no visible lesions.

Time in transit did not affect the incidence of DOA in this study (Table 10). There was a limited range in transportation length so this result may be expected. Since environmental conditions on the transport vehicles are relatively stable, it seems likely that moderate transportation times should not affect death loss.

TABLE 8. The effect of ambient temperature on bird death

Ambient temperature	# of trips	DOA[1] (%)	DOS[2] (%)
< -16.0°C	3	0.27[a]	0.50[a]
-15.9 to –6.0°C	5	0.12[b]	0.31[ab]
-5.9 to 5.9°C	7	0.13[b]	0.21[b]
6.0 to 15.9°C	8	0.12[b]	0.24[b]
>16.0°C	3	0.11[b]	0.23[b]

[1] DOA – dead immediately upon arrival at the slaughtering plant.
[2] DOS – dead at shackling immediately prior to slaughter. Time in lairage ranged from 170 to 305 minutes (235 min average) after arrival at slaughtering plant.
[a,b] Means within columns with different superscripts are significantly different (P<0.05).

TABLE 9. Necropsy findings for broilers found dead on arrival (DOA) at the slaughtering plant from 3 cold journeys (< -16°C)

	Number of DOA birds		
Cause of death	Cold journey 1	Cold journey 2	Cold journey 3
Ascites	3	0	18
Cyanosis	1	0	1
Dislocated hip	0	1	3
Head trauma	0	4	4
No visible lesions	7	7	18
Other	1	0	2
TOTAL DOA (%)	0.15	0.15	0.52

TABLE 10. Effect of transportation time on the percentage of birds dead on arrival (DOA)

Length of journey	# of journeys	DOA (%)
120-145 min	2	0.14
150-175 min	12	0.15
180-205 min	11	0.12
210-240 min	1	0.16

Since the plant has noted higher numbers of dead birds at shackling, it was also of interest to compare DOA data to the total death loss that occurred prior to shackling of the loads monitored in this study. Dead on shackling (DOS) data were obtained from the processing plant and are presented in Table 6. The mean DOS for the 26 trips was 0.27% with a range from 0.11 to 0.90%. As with DOA, the proportion of DOS birds was highest for trips where the ambient temperature was < -16°C (Table 8). The birds from these trips were shackled within 170 to 305 min of arrival at the processing plant, which is a relatively short holding period. Some birds are kept in lairage for longer periods of time and this undoubtedly contributes to a higher level of death loss.

The focus of the DOA analysis was on birds dying in transit but the impact of adverse transport conditions can have affected later death loss. The process of catching birds at the broiler farm, transportation to and storage at the processing plant can all affect death loss and it is important that the quality of management and the environment during the entire process be adequate to ensure satisfactory animal care and product (meat) quality.

Barn and bird condition

Atmospheric ammonia, bird condition and litter quality were assessed on farm. Mean atmospheric ammonia levels according to ambient temperature are shown in Table 11. There is a tendency for barn ammonia concentrations to be higher under cold weather conditions, and this trend is likely a reflection of lower ventilation rates during these periods.

TABLE 11. Effects of ambient temperature on atmospheric ammonia

Ambient temperature	Ammonia reading (ppm)		
	Mean	Minimum	Maximum
< -16.0°C	25	20	35
-15.9°C to –6.0°C	31	10	50
-5.9°C to 5.9°C	19	9	43
6.0°C to 15.9°C	10	2	30
>16.0°C	7	4	9

Bird quality assessment performed for this research was based on uniformity, leg problems, culls birds, feathering appearance and texture, and dead birds lying on the litter. Additionally, the truck driver appraised on-farm bird condition and their evaluating system included several categories: clean dry; breast dirty/wet; breast, crop and vent dirty/wet; and dirty/wet beyond breast, crop and vent. The majority of flocks were all in good condition (Table 12). Litter quality was scored according to areas of caking, feed spillage, depth of coverage and moisture. All barns had good to average litter conditions (Table 12). The litter assessment results were similar to those reported by the catching crew, which categorized the litter condition as very dry, damp, wet or very wet.

TABLE 12. The effect of ambient temperature on bird and litter quality assessed by the research team and processing company

Ambient temp.	No. of trips	Research assessment						Company assessment			
		Bird quality			Litter quality			Bird quality		Litter quality	
		G[1]	AV[1]	P[1]	G	AV	P	A[2]	B[2]	VD[3]	D[3]
< -16.0°C	3	3	-	-	2	1	-	3	-	2	1
-15.9°C to –6.0°C	6	5	1	-	2	4	-	6	-	6	-
-5.9°C to 5.9°C	7	4	3	-	2	5	-	6	1	4	3
6.0°C to 15.9°C	8	5	2	1	5	3	-	8	-	6	2
>16.0°C	3	2	1	-	3	-	-	3	-	3	-

[1] G=good; AV=average; P=poor.
[2] A=clean dry; B=breast dirty.
[3] VD=very dry; D=damp.

Litter moisture analysis was performed on paired litter samples (one from the main floor and one within close proximity to the drinkers) from 13 farms. Eight litter samples were collected when the ambient temperature was below 0°C (temperature range from –27.2 to –0.1°C) and five were collected when the outdoor temperature was below 0°C (temperature range from 7.9 to 17.5°C). As expected, average litter moisture content around the watering lines was higher than the main floor areas (38.0%, range: 22.7 to 49.4%; and 17.3%, range: 11.6 to 28.0%, respectively). Ambient temperature had little effect on the litter moisture content from the barns sampled (Figure 36).

Overall, the barns visited in this study were well managed and contained birds in good condition. It must be emphasized that on-farm conditions can influence the impact that transportation-associated stressors have on birds.

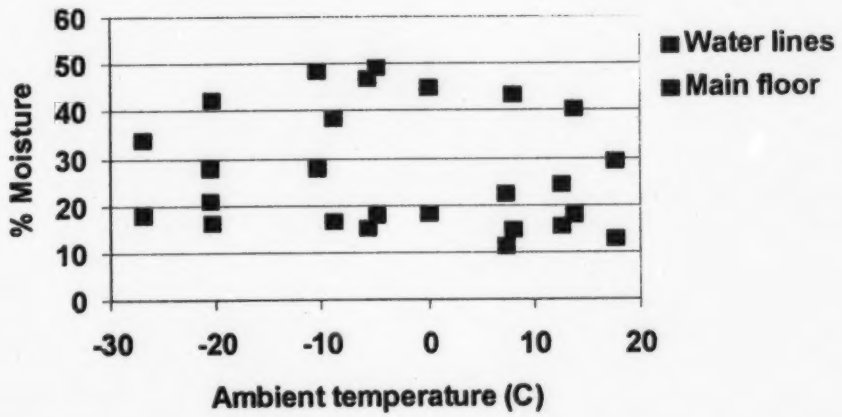

Figure 36. Litter moisture content (%) of litter samples from the main floor and in close proximity to the watering lines.

Conclusions

Low-temperature transportation

Winter transportation of broilers in Saskatchewan presents a considerable challenge. On one hand, the birds must be protected from the freezing ambient temperature, but on the other, air exchange on the transport vehicle is required for removal of moisture and heat being produced by the birds and for provision of adequate levels of oxygen. Therefore, air circulation is required to provide for minimum ventilation rates. Although roof vents can be used to control air exchange to some degree (Figure 16), passive airflow of this type is difficult to estimate because of the influence of vent location, truck speed, prevailing winds, bird stocking density, etc. Similarly, air does not enter the trailer in a planned fashion. It basically enters in response to pressure differentials on the moving vehicle and available openings. There are no planned inlets. Therefore, air enters primarily at the edges of the tarps (rear, bottom and front) as they are difficult to seal, through unintentional openings (poorly sealed front vents) or through roof vents. In the case of roof vents, entry is more likely to occur in vents near the back of the vehicle because of reduced exterior negative pressures on the trailer in this location. Modules containing broilers block airflow and thereby influence the degree of ventilation that occurs in various sections of the trailer. The above factors result in heterogeneous temperature distribution from very cold near air inlets to quite warm in poorly ventilated areas.

Recommendations to industry for improving conditions in passively ventilated broiler transport vehicles include:

- Before cold weather transportation, ensure the headboard and rear vents are in good condition and properly sealed.
- Tarping influences air flow through the trailer. Truck drivers should be aware of tarp and bungee cord condition. If the bungee cord used to secure the tarp has lost its elasticity, it should be replaced.
- Investigate other methods of securing the tarp, particularly for extremely cold weather. Although we did not see high levels of mortality on cold trips, industry experience indicates that this can happen in areas where air enters the trailer. Under very cold conditions, points of air entry should not allow air to flow directly onto the birds.
- Consider the use of smaller roof vents to control airflow and provide more uniform ventilation.
- Distribute vent openings over the front half of the vehicle to reduce the potential of air short circuiting the load and entering in close proximity to the exhaust vent. This should increase the temperature at the floor level of the vehicle directly under the vents.
- Modules and crates should be dry before use under winter conditions. Once unloaded, trailer units are washed in the live receiving area of the plant and immediately taken out of the facility. In cold temperatures the modules and crates do not dry and therefore, water freezes to the equipment. Birds loaded into these containers produce enough heat to melt the ice and this moisture may contribute to the compromising conditions encountered in cold weather transport. Drying freshly cleaned modules would alleviate this problem.

- Real-time temperature sensors could be used to assist drivers. Vent adjustments could then be made according to on-board conditions.
- Shorten the lairage period prior to processing. This could be accomplished by altering the catching schedule to coincide with the processing shifts.
- Improve lairage facilities. A heated and well-ventilated holding area for birds awaiting processing would be beneficial.

Recommendation to producers:

- Good bird condition prior to transportation is essential. Birds with existing disease will be predisposed to transport stressors, as will damp birds, particularly in cold weather transportation. Proper drinker management, and adequate barn heating and ventilation are on-farm factors that will ensure birds are loaded onto the trailer units in dry condition.

<u>High-temperature transportation</u>

Recommendations to industry:

- Passively ventilated transport trailers provide acceptable on-board thermal conditions, provided that the vehicle remains in motion. Truck stoppage during the transit period should be kept short to avoid potentially dangerous thermal developments. Real-time temperature sensors placed within the load may be useful for monitoring conditions during periods when the vehicle is stationary. Logger placement in the hot spot on the truck (directly behind the step in the trailer frame, nearest the floor) would be appropriate.
- Lairage facilities capable of providing adequate air circulation while birds await processing would be of benefit.

Overall, the industry is doing a reasonable job operating a broiler transport system that allows little control besides the adjustment of roof vents and trailer tarps.

An objective of this study was to develop a model for transportation of broiler chickens and test the model under commercial conditions of Saskatchewan. However, additional engineering research is required for this step. NSERC/AAFC funding has been obtained to complete this experimentation and is already underway.

General on-farm conclusions:
The DOA necropsy results indicate that farm management affects the level of bird loss during transport. In the case of chronic heart disease (ascites, cyanosis), this entails maintaining appropriate barn temperatures and air quality (dust, ammonia), which are known to impact heart function. Disease prevention management is essential to reduce the potential for infected birds to die in transit. A newsletter reviewing barn management factors such as temperature control, ventilation rates and tolerable levels of pollutants will be distributed to producers through the Poultry Extension Service to assist with management strategy.

5. References

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OTHER RELATED INFORMATION

- This project is part of the M.Sc. research of Ms. Tennille Knezacek.

- Drs. Trever Crowe, E.M. Barber and H.L. Classen have successfully applied to NSERC (Partnership Agreement with Agriculture and Agri-Food Canada) to extend the engineering components of this research. Four years of monetary support with equal amounts coming from AAFC and NSERC has been approved. The total funding available is $217,000. (Year 1 - $42,500; Year 2 - $47,500; Year 3 - $82,000; Year 4 - $45,000) The current studies involving environmental conditions within broiler-transport vehicles must be expanded, with particular emphasis on engineering components of the problem.

- Abstract presented at the Poultry Science Association Annual Meeting in Montreal, August 18-20, 2000.
  T.D. Knezacek[1*], G.F. Audren[1], M.A. Mitchell[2], P.J. Kettlewell[3], R. Hunter[2], H.L. Classen[1], S. Stephens[1], A.A. Olkowski[1], E.M. Barber[1], and T.G. Crowe[1], 2000. Temperature heterogeneity and moisture accumulation in trailers transporting broilers under Canadian winter conditions. Poultry Science 79:31 (Abstract).

- Abstract presented at the Poultry Science Association Annual Meeting in Indianapolis, July of 2001.
  T.D. Knezacek, G. P. Audren, H. L. Classen, E.M. Barber, T.G. Crowe, and S. Stephens, 2001. Temperature gradients in trailers transporting broilers under Canadian winter conditions. Poultry Science 80:39(Abstract).

- Abstract submitted for presentation at the annual conference of the Agricultural Institute of Canada (AIC) and the Canadian Society for Engineering in Agricultural, Food and Biological Systems (CSAE/SCGR), July 14-17, 2002.
  T.D. Knezacek, H.L. Classen, T.G. Crowe, E.M. Barber, and G.P Audren. Thermal variation in passively ventilated broiler chicken transport vehicles. CSAE 02-508.

- Industry reports:
  Presentation to Lilydale personnel in Wynyard, SK, November 24, 2001. "Transporting Broilers under Saskatchewan Winter Conditions."
  Presentation at Saskatchewan Poultry Industry Conference in Saskatoon, SK, March 8, 2002. "Broiler Transportation in Saskatchewan."

4. Personnel:

   Tennille Knezacek – M.Sc. Candidate – 24 months (Mar 01, 2000 to Feb 28, 2002)

5. Equipment: N/A

6. Project Developed Materials: N/A

7. Project Photos:

   See Figures 1 and 4-6 for examples.

8. Acknowledgements:

- The Chicken Farmers of Saskatchewan are co-sponsors of the research
- Lilydale personnel: C. Gudmundson, M. Karakochuk and truck drivers, including B. Bell, W. Bodnarchuk, A. Bucko, G. Gelech, W. Jackson and R. Karakochuk
- CFIA veterinarians: Drs. B. Althouse, D.S. Derow, and L. Belanger
- Broiler catching crews
- Producers participating in the study:
  A. Buhler, Grand Slam/Shay Don, H. Huizinga, JCJ Poultry, N. Keet, T. Kleinsasser, N. Langelaar, D. Neufeld, M. Pickard, L. Regehr, P. Regehr, N. Sloboshan, W. Sloboshan, A. Wohlgemuth, M. Wohlgemuth
- Technical assistance provided by Robert Gonda, Karen Schwean and Dawn Abbott.

9. Expense Statement: Budget to follow.

APPENDIX A

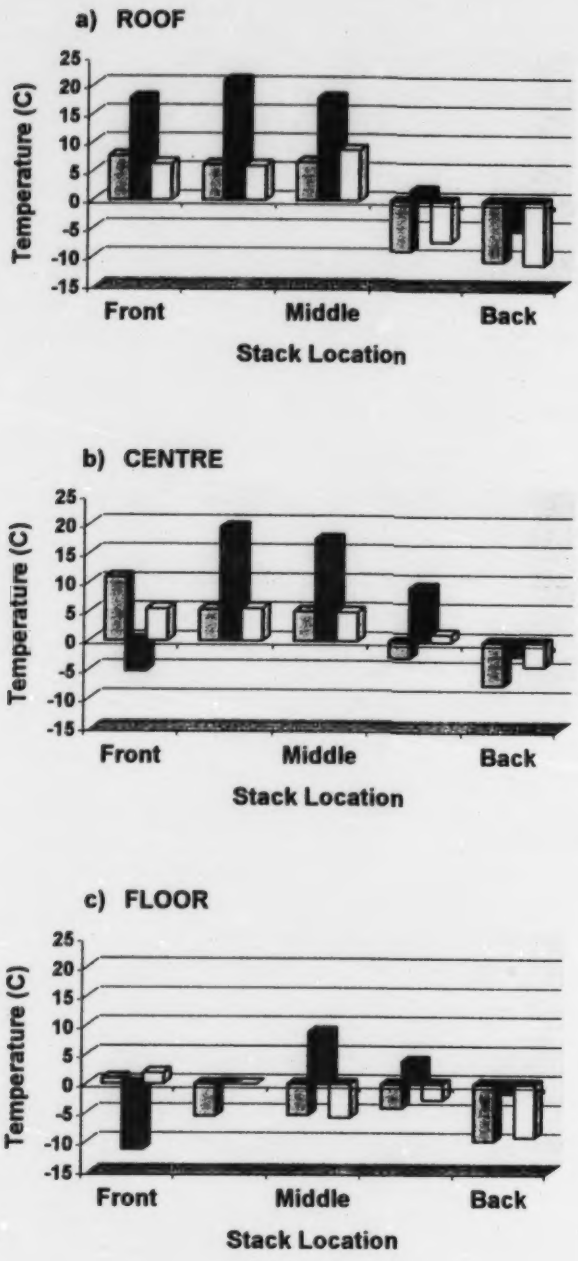

Figure 17. Crate temperature recorded in different stack locations from journeys completed when ambient temperature was below -16.0 C, both tarps were lowered, front and rear vents were closed, and roof vents 1 and 5 were open. a) loggers placed nearest the roof; b) loggers in the centre of the stack; c) loggers in close proximity to the trailer floor.

Driver Middle Passenger

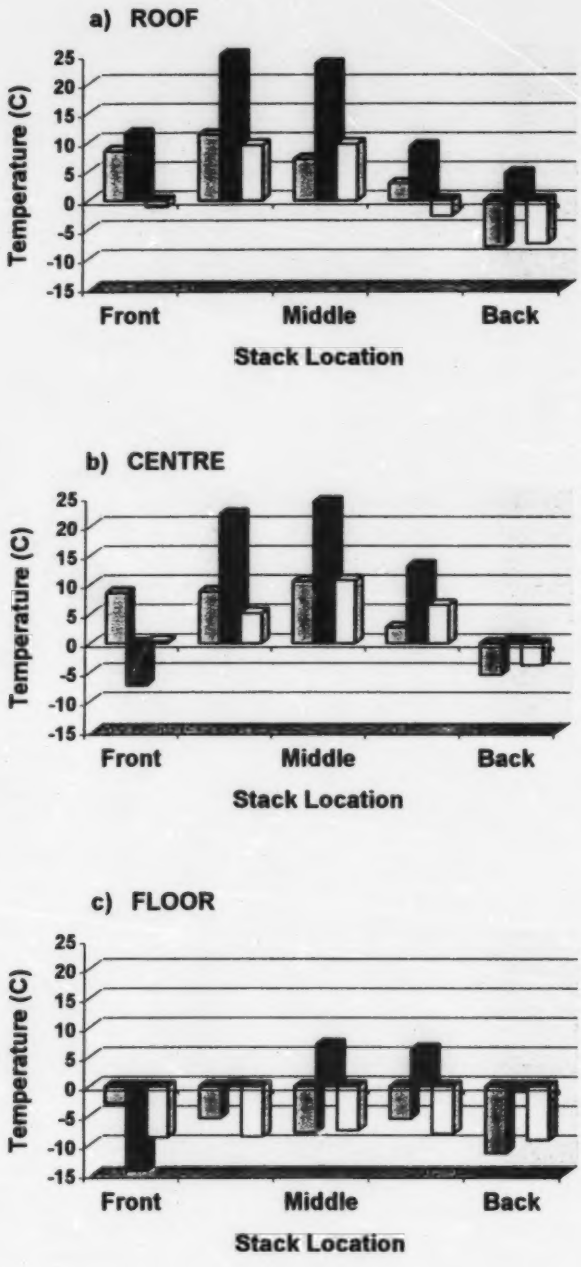

Figure 18. Crate temperature recorded in different stack locations from journeys completed when ambient temperature was below -16.0 C, both tarps were lowered, front and rear vents were closed, and roof vent 1 was open. a) loggers placed nearest the roof; b) loggers in the centre of the stack; c) loggers in close proximity to the trailer floor.

Driver Middle Passenger

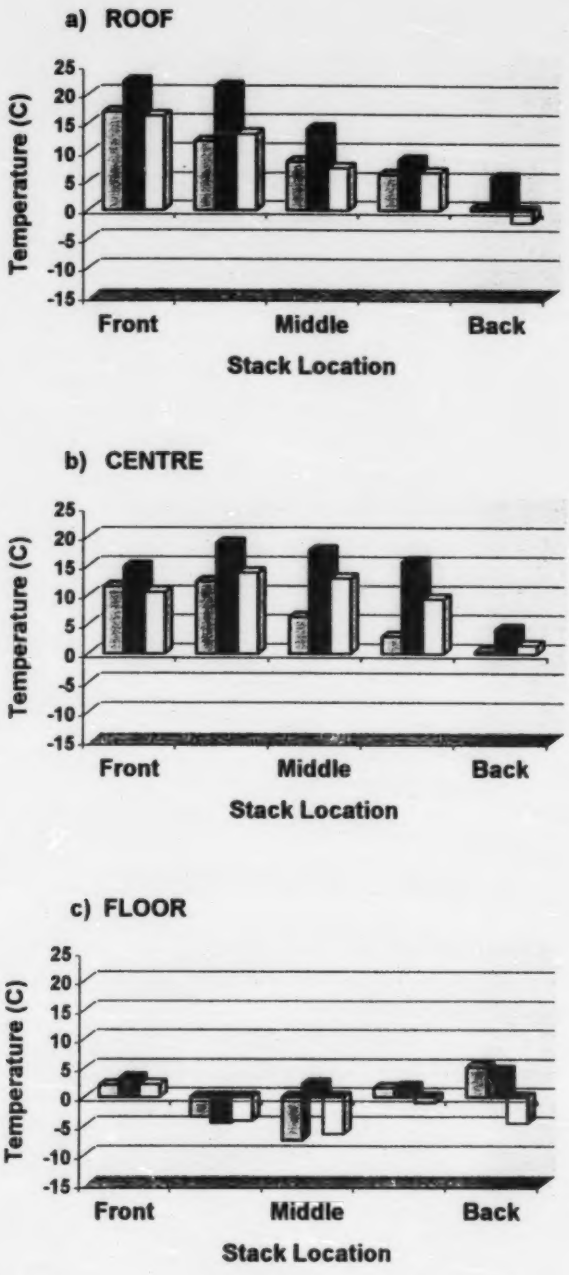

Figure 19. Crate temperature recorded in different stack locations from journeys completed when ambient temperature was below -16.0 C, both tarps were lowered, front and rear vents were closed, and only the back half of roof vent 5 was open. a) loggers placed nearest the roof; b) loggers in the centre of the stack; c) loggers in close proximity to the trailer floor.

Driver Middle Passenger

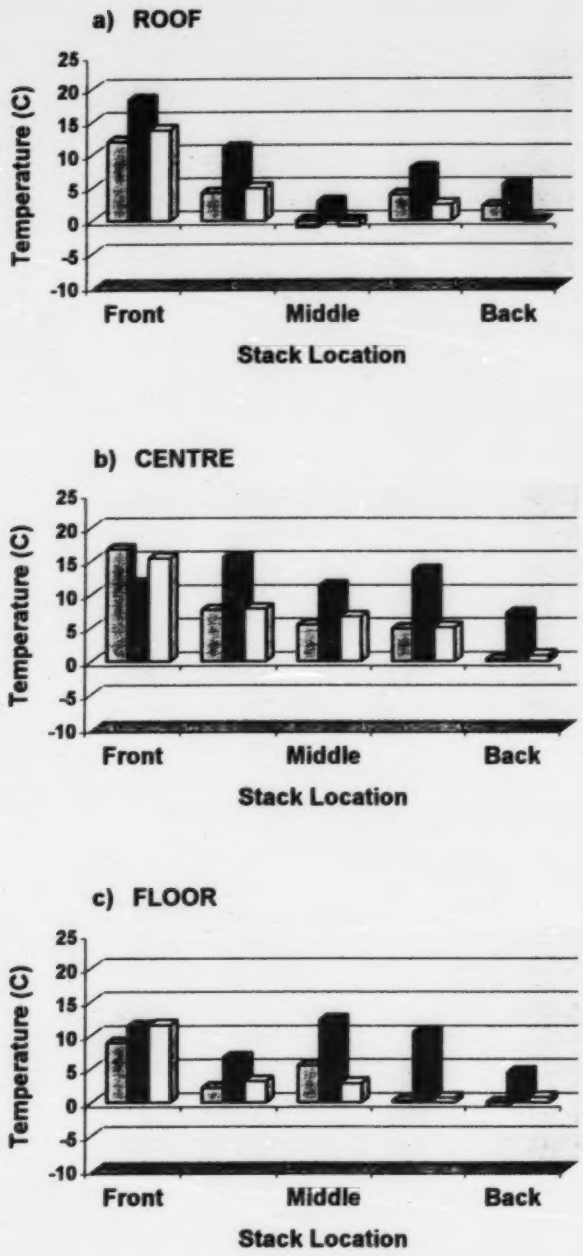

Figure 20. Crate temperature recorded in different stack locations from journeys completed when ambient temperature was -15.9 to -6.0 C, both tarps were lowered, front and rear vents were closed, and all roof vents (1-8) were open. a) loggers placed nearest the roof; b) loggers in the centre of the stack; c) loggers in close proximity to the trailer floor.

Driver Middle Passenger

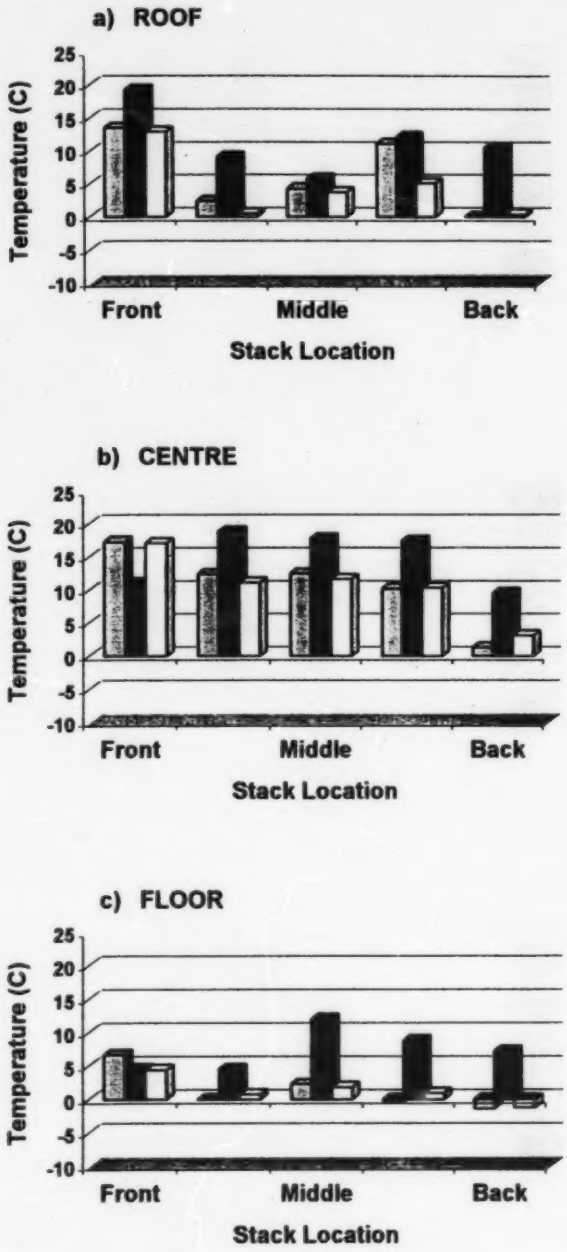

Figure 21. Crate temperature recorded in different stack locations from journeys completed when ambient temperature was -15.9 to -6.0 C, both tarps were lowered, front and rear vents were closed, and roof vents 1 and 2 were open. a) loggers placed nearest the roof; b) loggers in the centre of the stack; c) loggers in close proximity to the trailer floor.

Driver Middle Passenger

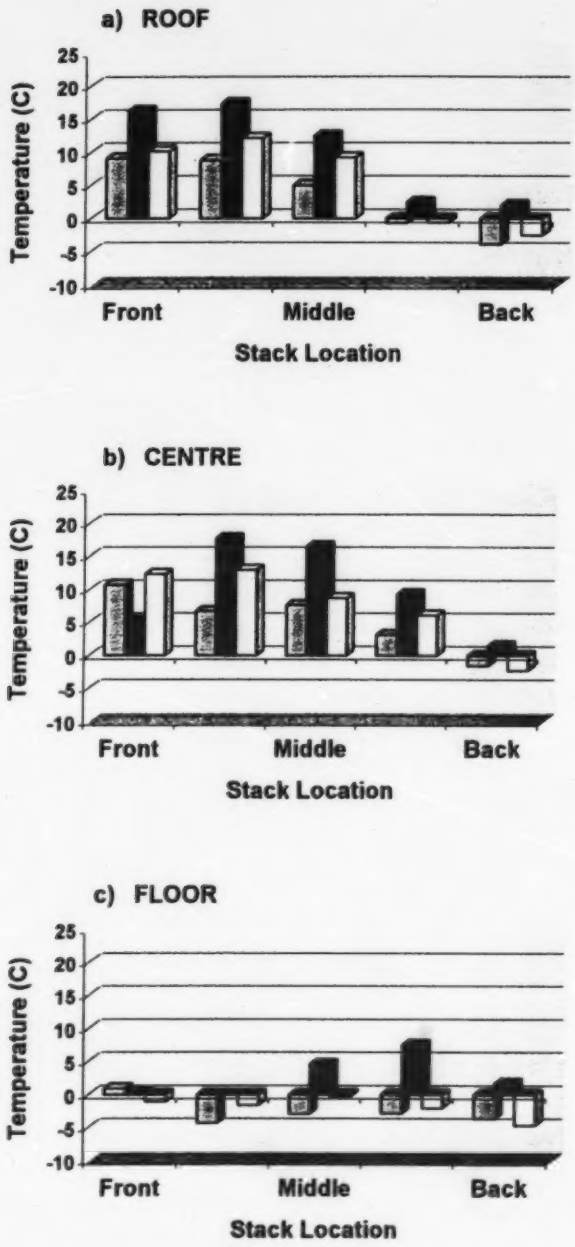

Figure 22. Crate temperature recorded in different stack locations from journeys completed when ambient temperature was -15.9 to -6.0 C, both tarps were lowered, front and rear vents were closed and roof vents 1, 5, and 8 were open. a) loggers placed nearest the roof; b) loggers in the centre of the stack; c) loggers in close proximity to the trailer floor.

Driver Middle Passenger

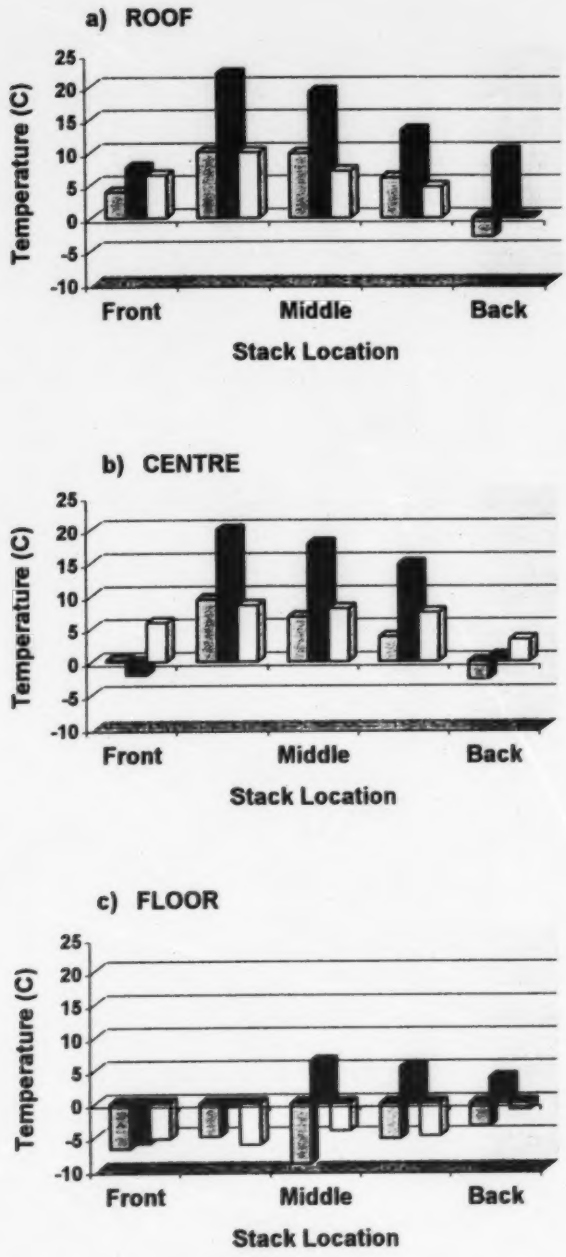

Figure 23. Crate temperature recorded in different stack locations from journeys completed when ambient temperature was -15.9 to -6.0 C, both tarps were lowered, front and rear vents were closed and roof vent 1 was open. a) loggers placed nearest the roof; b) loggers in the centre of the stack; c) loggers in close proximity to the trailer floor.

Driver Middle Passenger

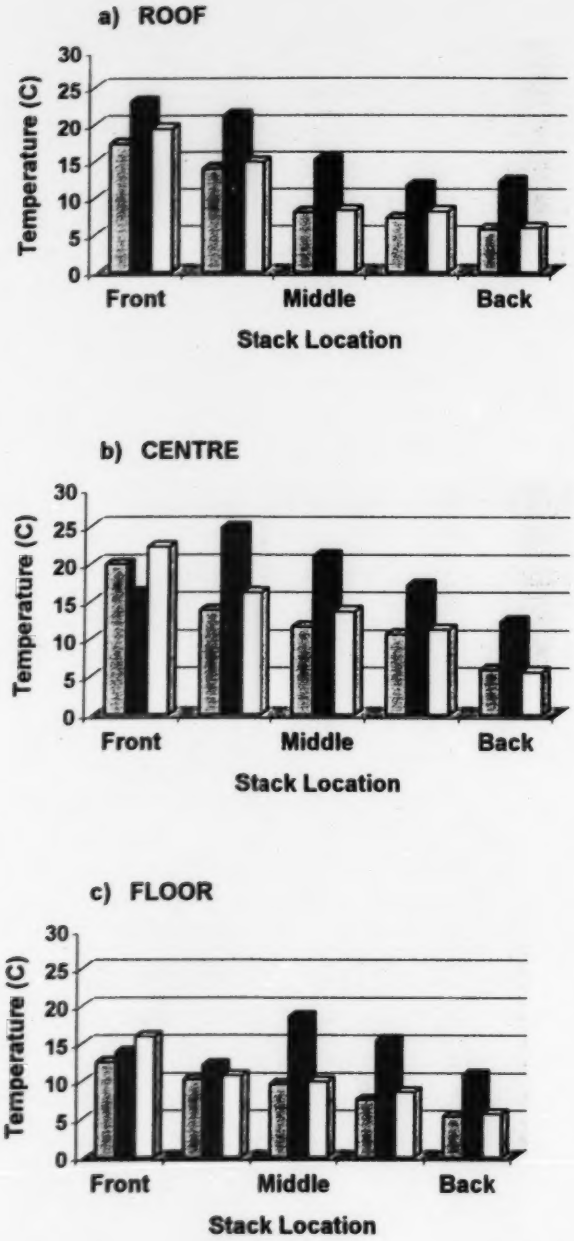

Figure 24. Crate temperature recorded in different stack locations from journeys completed when ambient temperature ranged from -5.9 to +5.9 C, both tarps were lowered, front and rear vents were closed and all roof vents (1-8) were open. a) loggers placed nearest the roof; b) loggers in the centre of the stack; c) loggers in close proximity to the trailer floor.

Driver Middle Passenger

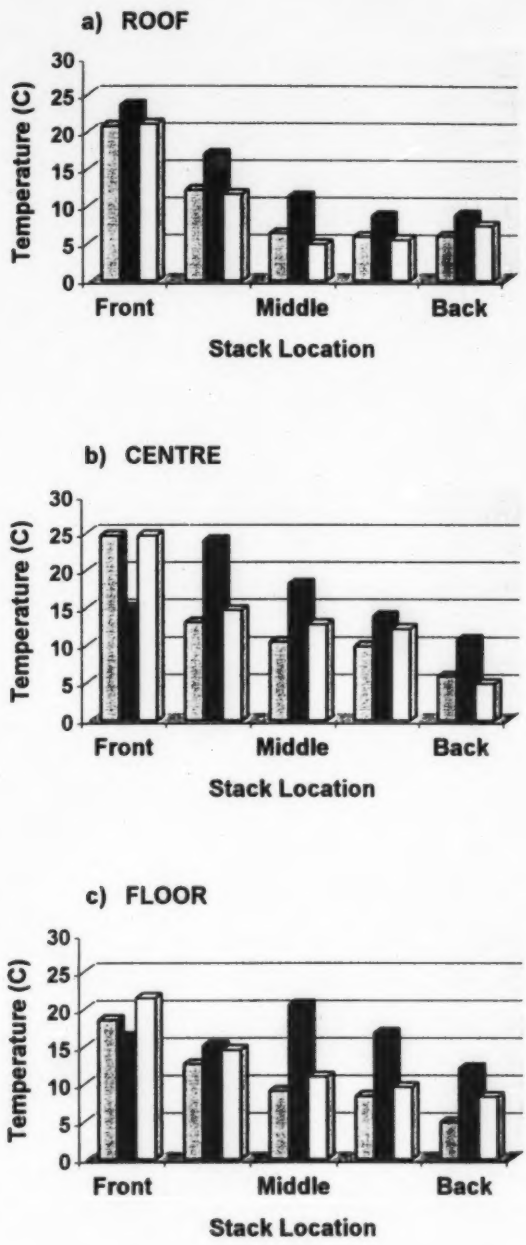

Figure 26. Crate temperature recorded in different stack locations from journeys completed when ambient temperature ranged from -5.9 to +5.9 C, both tarps were lowered, front and rear vents were closed and roof vents 1 to 4 were open. a) loggers placed nearest the roof; b) loggers in the centre of the stack; c) loggers in close proximity to the trailer floor.

Driver Middle Passenger

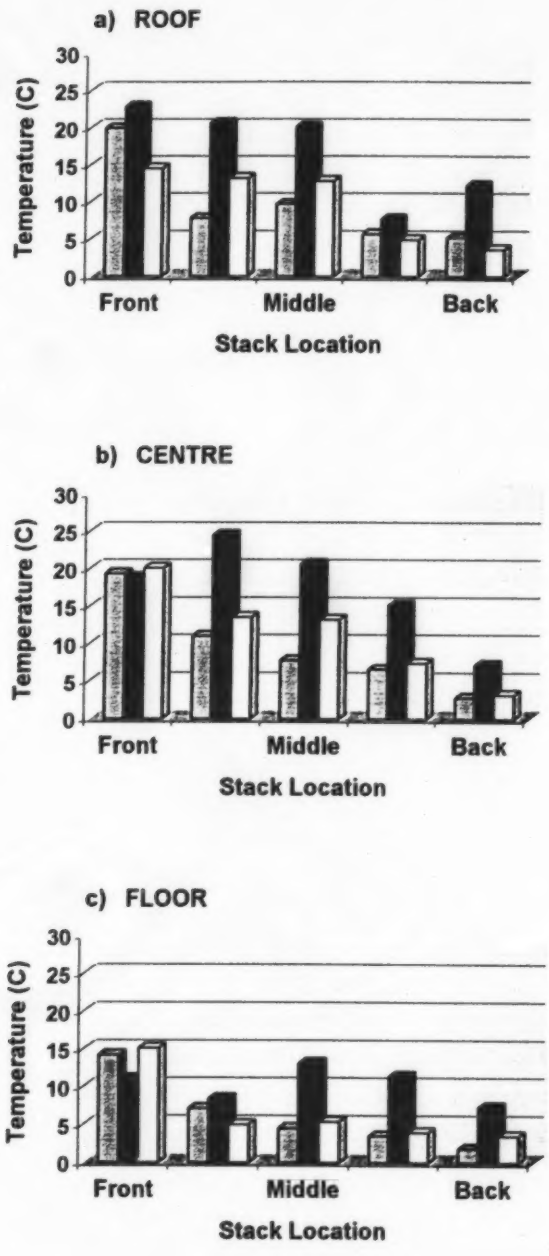

Figure 27. Crate temperature recorded in different stack locations from journeys completed when ambient temperature ranged from -5.9 to +5.9 C, both tarps were lowered, front and rear vents were closed and roof vents 1, 2, 5 and 6 were open. a) loggers placed nearest the roof; b) loggers in the centre of the stack; c) loggers in close proximity to the trailer floor.

Driver Middle Passenger

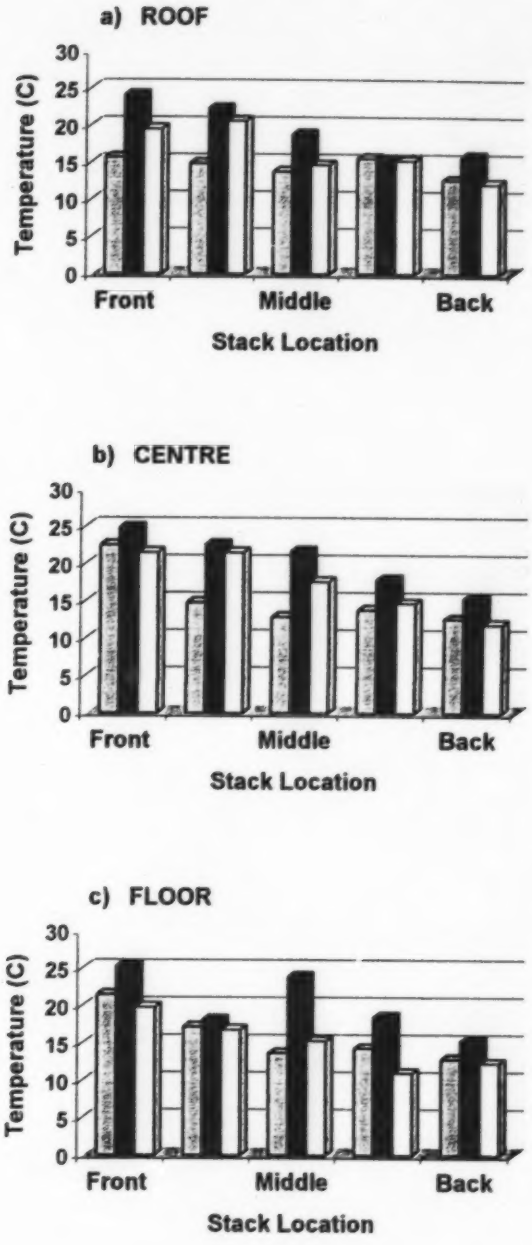

Figure 28. Crate temperature recorded in different stack locations from journeys completed when ambient temperature ranged from 6.0 to 15.9 C, front and rear vents were closed, all roof vents were open and both curtains were lowered. a) loggers placed nearest the roof; b) loggers in the centre of the stack; c) loggers in close proximity to the trailer floor.

Driver Middle Passenger

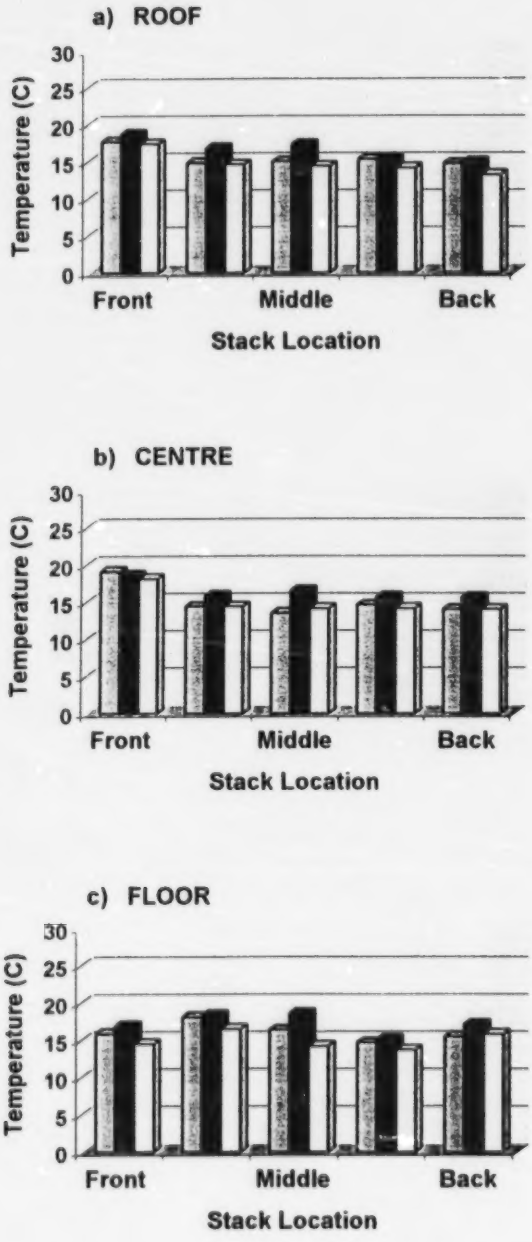

Figure 29. Crate temperature recorded in different stack locations from journeys completed when ambient temperature ranged from 6.0 to 15.9 C, front and rear vents were closed, all roof vents were open and both curtains were raised. a) loggers placed nearest the roof; b) loggers in the centre of the stack; c) loggers in close proximity to the trailer floor.

Driver Middle Passenger

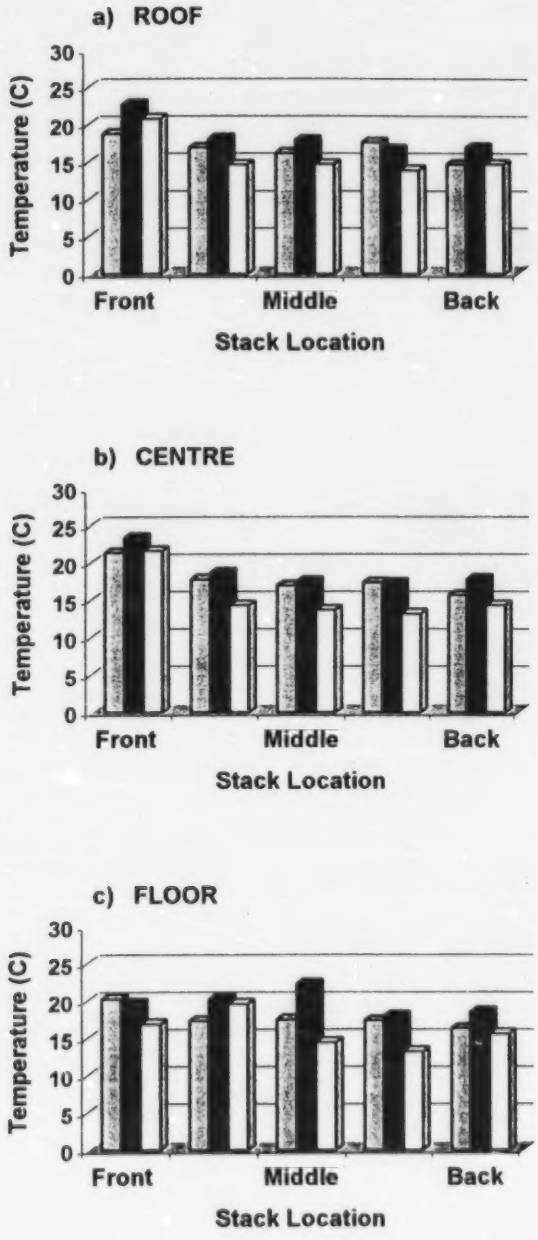

Figure 30. Crate temperature recorded in different stack locations from journeys completed when ambient temperature ranged from 6.0 to 15.9 C, front and rear vents were closed, all roof vents were open, the driver side curtain was lowered and the passenger side curtain was raised. a) loggers placed nearest the roof; b) loggers in the centre of the stack; c) loggers in close proximity to the trailer floor.

Driver Middle Passenger

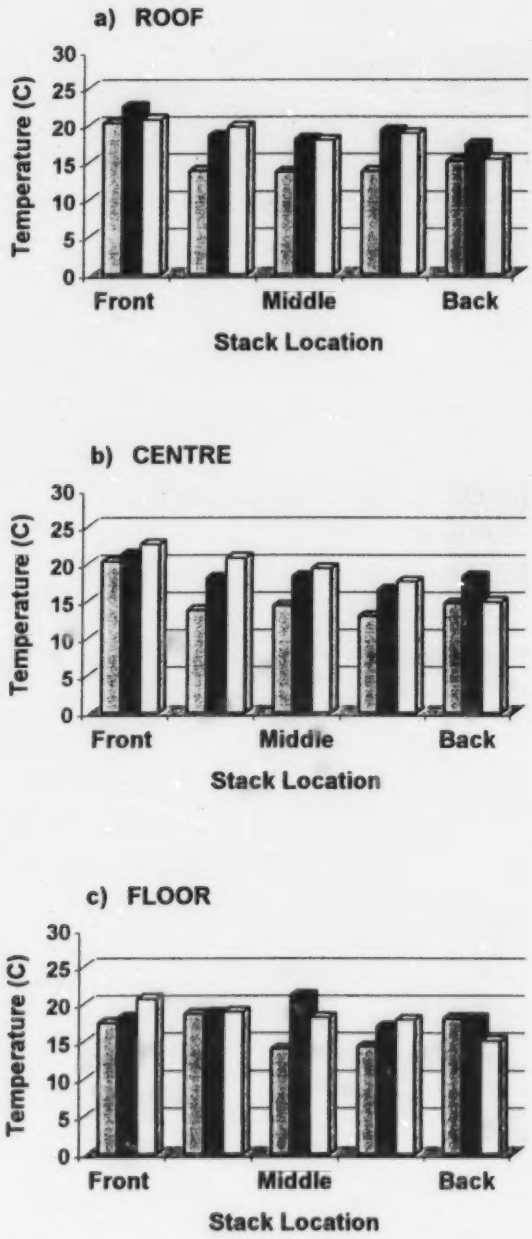

Figure 31. Crate temperature recorded in different stack locations from journeys completed when ambient temperature ranged from 6.0 to 15.9 C, front and rear vents were closed, all roof vents were open, the driver side curtain was raised and the passenger side curtain was lowered. a) loggers placed nearest the roof; b) loggers in the centre of the stack; c) loggers in close proximity to the trailer floor

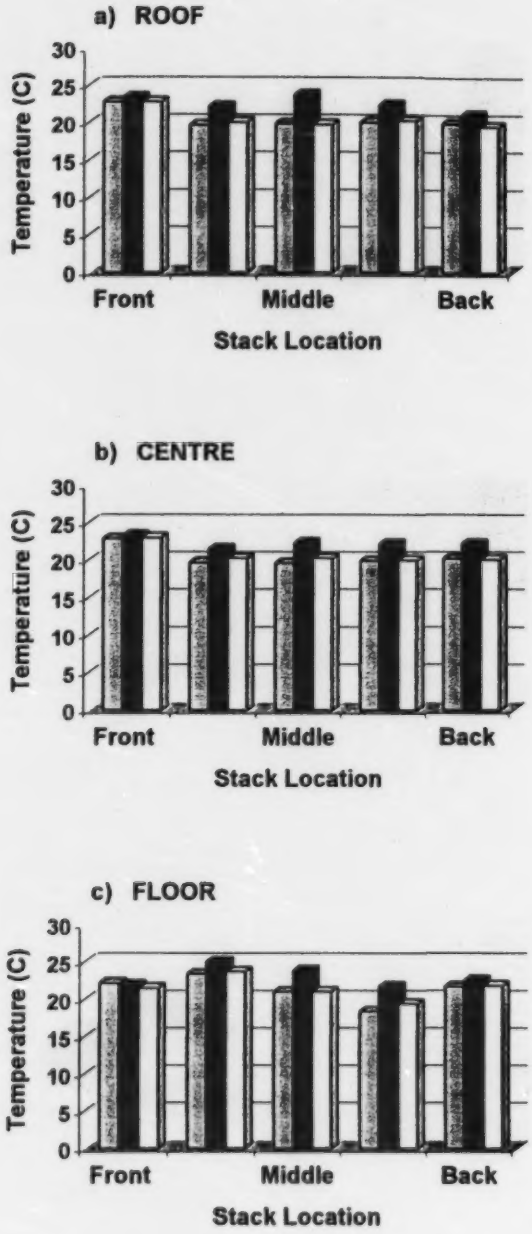

Figure 32. Crate temperature recorded in different stack locations from journeys completed when ambient temperature was above 16.0 C, all roof vents were open, both curtains were raised and the front and rear vents were closed. a) loggers placed nearest the roof; b) loggers in the centre of the stack; c) loggers in close proximity to the trailer floor.

Driver Middle Passenger

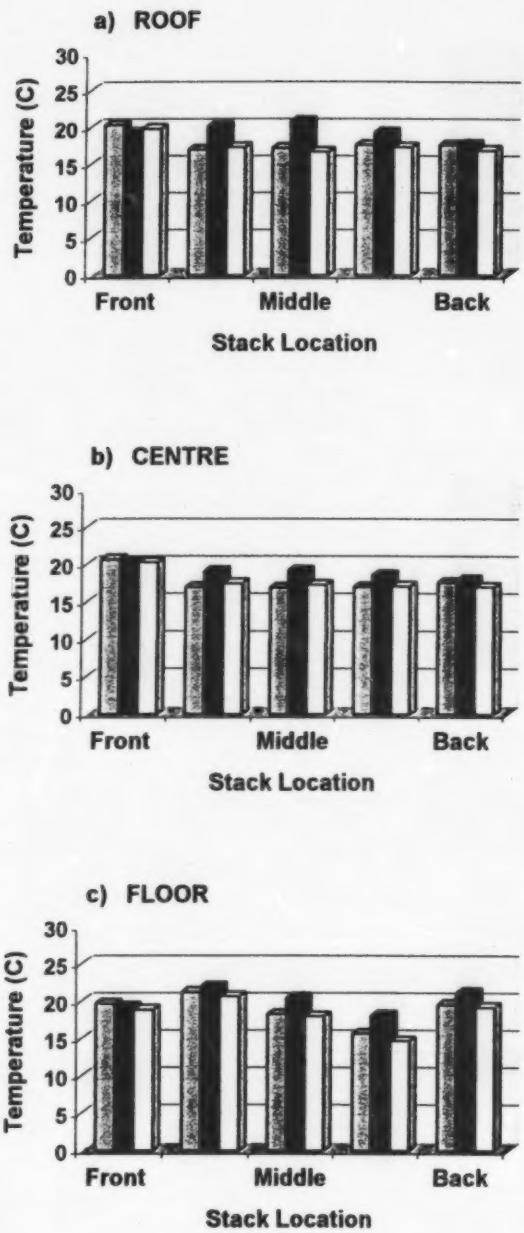

Figure 33. Crate temperature recorded in different stack locations from journeys completed when ambient temperature was above 16.0 C, all roof vents were open, both curtains were raised and front and rear vents were open. a) loggers placed nearest the roof; b) loggers in the centre of the stack; c) loggers in close proximity to the trailer floor.

Driver Middle Passenger

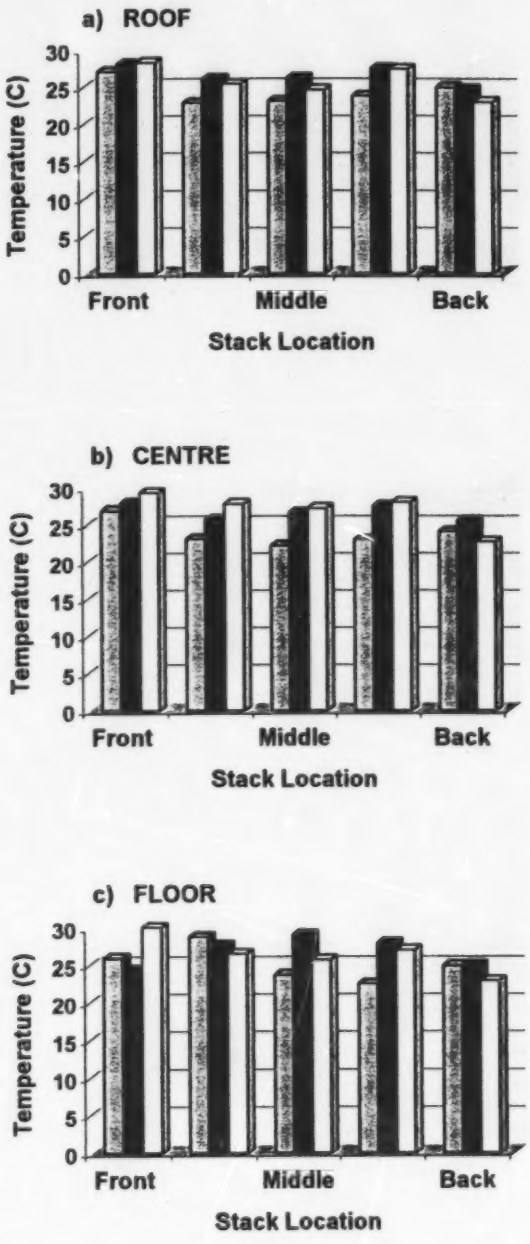

Figure 34. Crate temperature recorded in different stack locations from journeys completed when ambient temperature was above 16.0 C, all roof vents were open, front and rear vents were closed, the driver side curtain was raised and the passenger side curtain was lowered. a) loggers placed nearest the roof; b) loggers in the centre of the stack; c) loggers in close proximity to the trailer floor.

Driver Middle Passenger